UNITED STATES AGENCY FOR INTERNATIONAL DEVELOPMENT

ARMENIA ESCO DEVELOPMENT PROGRAM

LAG-OUT-I-00-98-00004-00
Task Order #807

RESULTS ANALYSIS REPORT

JULY 10, 2000

Submitted by:

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1. Executive Summary

The Energy Service Company (ESCO) Development Program, funded by the US Agency for International Development (USAID), builds upon previous USAID-funded activities in Armenia including weatherization, energy efficiency and other ESCO programs. USAID contracted with Advanced Engineering Associates, International (AEAI) under the Global Bureau Energy IQC (Contract #LAG-I-00-98-00004-00, Task Order #807) to implement the ESCO Development Program. AEAI subcontracted with Resource Management Associates, Inc. to provide technical assistance for the program. The Task Order was signed on March 15, 1999 and had an initial completion date of March 15, 2000. An extension was granted for the program in order to complete the installation activities, and the new completion date was established as June 9, 2000. All activities are completed with the submission of this report.

1.1 Program Background

The goal of the Task Order was to assist with the establishment of private ESCOs to continue existing energy conservation activities, thereby laying the foundation for ESCOs that will ultimately provide conservation and energy efficiency services to the industrial, commercial and residential sectors. The Task Order calls for a continuation of past weatherization and heating system improvement activities, but with a major focus on developing private ESCOs to carry out integrated weatherization and heating system improvement projects that benefit vulnerable groups. The Task Order was designed to support USAID's three strategic objectives (or Intermediate Results – IRs) aimed at attaining a more economically sustainable and environmentally sound energy sector in 5-7 years:

- IR 1: Increased private sector participation in the energy sector.
- IR2: Increased economic efficiency in the energy sector.
- IR3: Reduced environmental hazards of operating Medzamor NPP.

The Task Order consisted of four major activities:

1. Development of a Portfolio of Integrated Weatherization/Heating System Improvement Projects
2. Identification and Strengthening of Existing ESCOs
3. Weatherize Buildings/Improve Heating Systems Using Competitively Selected ESCOs
4. Monitoring, Evaluation and Dissemination of Results

Four schools were selected to implement a combined weatherization/heating system project: School #15 in Giumri, School #1 in Spitak, and in Yerevan, School #132 and School Shirvanzade. A total of eleven private companies and one energy NGO participated in various aspects of the program, in project management, weatherization, heating systems design, construction of gas lines, heating systems installation and training. Several local companies also provided equipment and materials for the project, including pumps, gas line piping, weatherization materials, glass, insulated doors and other materials. All of the work was competitively bid among the ESCOs interested in providing services.

Two workshops were held under the project: a one week workshop, held in conjunction with the Association for Energy Engineers, for ESCOs and others who were interested in participating in the program, and a two-day workshop on heating systems strategy in Armenia, organized in conjunction with the UNDP/GEF Project Unit focusing on Climate Change. In the ESCO workshop, topics included energy auditing and accounting, energy efficiency technologies, ESCO marketing strategies, energy efficiency project finance, and performance contracting. The workshop on heating systems strategy included training on strategic planning and decision analysis software packages

(STRUCTURE and DECIDE). These models will be used by various local groups (university, Ministry of Energy, UNDP/GEF Climate Change Group) to provide input into the development of Armenia's heating sector strategy. Project personnel also participated in a seminar on energy efficiency organized by the ACAEE.

The work activities were managed on a daily basis by the in-country project management company, Resource Management of Armenia (RMAr). Their responsibilities included providing technical assistance to the ESCOs as needed, overseeing the work and quality control inspections, local procurement, program impact assessment, and coordination of work among the ESCOs, schools and USAID contractors. All work activities were successfully completed on time and within the budget.

An evaluation of the ESCO Development Program was conducted to assess its results and the progress made towards meeting the program's objectives. The evaluation included qualitative and quantitative impact assessments. The results include enhancement of the skills and market opportunities for the ESCOs and the NGO that participated in the program, energy and cost savings for the schools, and dramatically improved comfort levels for the schools' occupants. Other important program impacts include the initiation of a dialogue on developing a heating systems strategy for Armenia in general, and a program of stand-alone boilers and weatherization of Armenia's schools. Both donor organizations and Armenian government organizations expressed great interest in the results of the program.

1.2 Recommendations for Future Activities

This program has provided a very important contribution to the dialogue on decentralization vs. rehabilitation of Armenia's central heating systems. It has also provided solid experience to the ESCOs that participated in the program in what to expect in cutting a building off from the district heating system, and rehabilitation of the building's internal distribution network. Data on cost of energy efficient boilers, installation costs, and construction costs are also available. To support decision-making on energy efficiency strategy, the future rehabilitation and development of Armenia's heating sector strategy and to further develop the ESCOs, the following additional work should be considered by USAID:

1. Heating Systems Strategy Development and Pilot Projects: A momentum is building to address long-term solutions to heat supply in Armenia. The ESCO Development Project sponsored a workshop on heat supply strategy that brought together key stakeholders to discuss the issues. In addition, the World Bank will provide a grant for strategy development that will identify barriers and constraints to solving this problem. It is expected that the solution will be rather a diffuse strategy involving both public and private elements. Pilot projects, especially in the residential sector, will help to overcome barriers to private sector approaches.

2. Further ESCO Development – ESCOs can continue to provide weatherization and heating system installation services in the private sector, but can also expand their markets to other services, such as renewables, public information, billing and collection for heat services, and local financing options. Future activities in energy efficiency should utilize the services of existing ESCOs to expand upon their knowledge and experience base, as well as develop new ESCOs.

3. Support to the Armenian Chapter of Association of Energy Engineers (ACAEE) - The ACAEE has a large membership of over 70 energy professionals, but constantly struggles with ways to provide a forum for exchange of ideas and member services with little or no funding. ACAEE is an organization that is worthy of support so that it can continue its advocacy of energy efficiency and rational energy policies in the development of Armenia's energy future. Support

to the Chapter could include English language training (so members can read the materials from the US); audit equipment to be loaned for a small fee to members and non-members; CEM training workshops for members; newsletter publication; other information dissemination; and office equipment such as a copier.

4. Energy Efficiency Education Program in Schools – Energy education in the schools could be a very cost-effective way of raising the awareness of the general population concerning ways that scarce and expensive energy resources can be conserved. Educating students and teachers is also important for maximizing the benefits of the energy efficient boiler installations in the schools. A curriculum could be designed based on materials used in the US, and an advertising campaign could be based on promotional materials produced by the students.

5. Energy Efficiency Fund - Together with other donor organizations, USAID could create an energy efficiency fund that will be used to implement cost-effective energy efficiency projects. This could alleviate one of the major barriers in Armenia.

2. School Heating Systems Impact Assessment

The impact assessment plan included both quantitative and qualitative aspects. This section describes the methodology that was used, and includes the summary results for both qualitative and quantitative assessments.

2.1 Quantitative Assessment Methodology

A data collection and analysis plan was developed to estimate the total quantitative economic impacts of the weatherization of windows and the use of high efficiency boiler for heating of school buildings. Data collection was performed over the winter 1999-2000. Temperature loggers were installed in the weatherized and non-weatherized rooms of each school building. Every 6 hours, data loggers recorded the temperatures of the outside air, the control rooms (weatherized and non-weatherized), and in the corridor at each of the locations. The infiltration air was measured twice a day in both the weatherized and non-weatherized control rooms.

The purpose of data collection during the monitoring period was to estimate the energy and economic impacts of the weatherization/high efficiency boiler combination. These impacts include: 1. Increase in the temperature in weatherized rooms, 2.Energy savings resulting from the weatherization, 3. Energy cost savings for heating due to weatherization, 4. Energy cost savings for heating due to high efficiency boiler, and 5. Determination of payback periods of the implemented energy efficiency measures.

Baseline energy use data was gathered in the energy audit, and reported in the “Weatherization and Heating Systems Project Report”. Given conditions in Armenia, past energy consumption does not provide sufficient data to establish potential energy savings. This is because there is inadequate heat provided in most institutions, with a heavy reliance on electric space heating or kerosene. In fact, two of the schools, Shirvanzade and Spitak, provided practically no heat this past winter. From a strictly financial point of view, the projects will not yield a payback in a reasonable period of time. For this reason, energy usage under more “normal” conditions is compared using electricity and the energy efficient boiler.

2.2 Summary Assessment of Building Conditions

This section summarizes the information related to the quantitative assessment activity. Data are presented for the four weatherized facilities and are followed by analytical and graphical representations of the weatherization and boiler implementation impacts. Energy savings, economics and simple payback calculations for each of the schools are included in Appendix A.

The comparison of the average values of measured temperatures and infiltrated air quantities demonstrates that the weatherization of windows significantly increases the inside temperatures and decreases the air infiltration by the average amounts shown in Table 1.

Table 1. Quantitative Results of Weatherization

School	Temperature Increase (C)	Reduction in Air Infiltration
School #1, Spitak	6.5 degrees C	14 m^3/hr/window
School #15, Giumri	11.5 degrees C	14 m^3/hr/window
School Shirvanzade, Yerevan	7 degrees C	12.4 m^3/hr/window
School #132, Yerevan	8.5 degrees C	12.5 m^3/hr/window

2.3 Individual School Assessments

2.3.1 School # 1 in Spitak

School #1 in Spitak was constructed in two stages, Block #1 in1998 and Block #2 in1999. A third block will be constructed in 2000. All blocks are constructed from tufa stone blocks. Sections of the building include:

Educational blocks - 2 floors, 36 rooms (20 classrooms, 10 administrative rooms, 6 toilets)
Gymnasium block – 1floor, gymnasium hall with 2 cloak-rooms

The school's operating capacity is 529 students in the existing blocks; 300 more will be added when the third block is constructed. The main sources of heating prior to boiler installation were electric and kerosene heaters. A new gas-fired boiler with 94% efficiency was installed along with weatherization of the windows and doors. The boiler was operated for a period of one month, from March 5 – April 10, 2000.

Monitoring Results

Figures 2.1 and 2.2 graphically depict the temperature of the outside air, weatherized and non-weatherized classrooms and the corridor at the School #1 in Spitak during the monitoring period. *Figure* 2.3 shows the difference in calculated heat losses between weatherized and non-weatherized rooms. *Figure* 2.4 shows the theoretical energy savings as a result of weatherization.

Figure 2.1
6:00 AM Temperature Measurements in School #1, Spitak

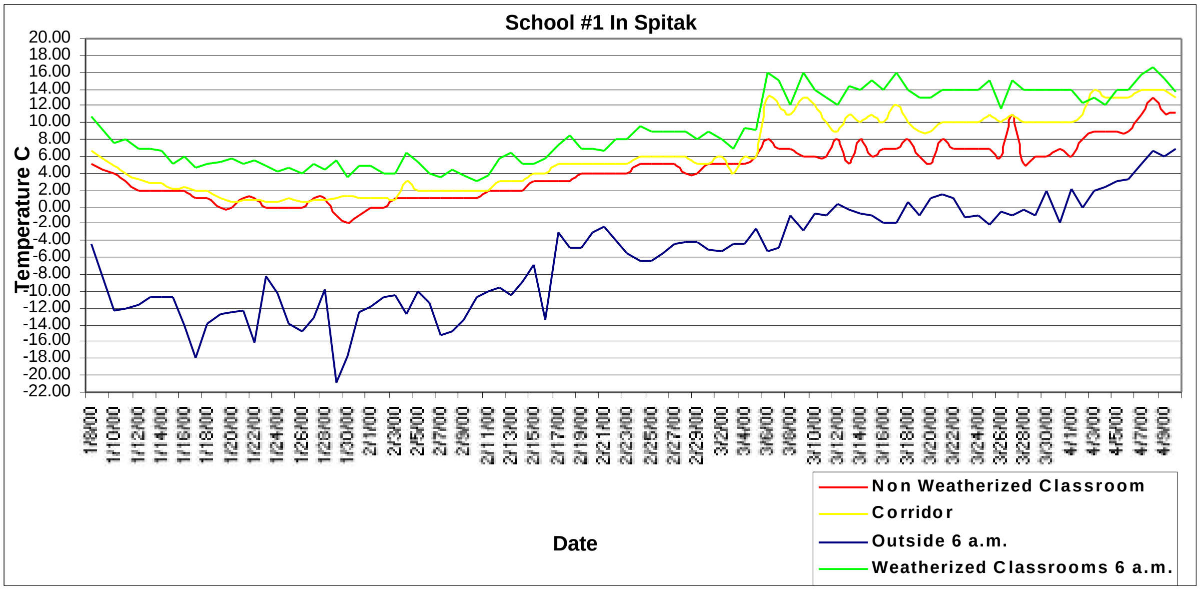


Figure 2.2
2:00 PM Temperature Measurements in Spitak, School #1

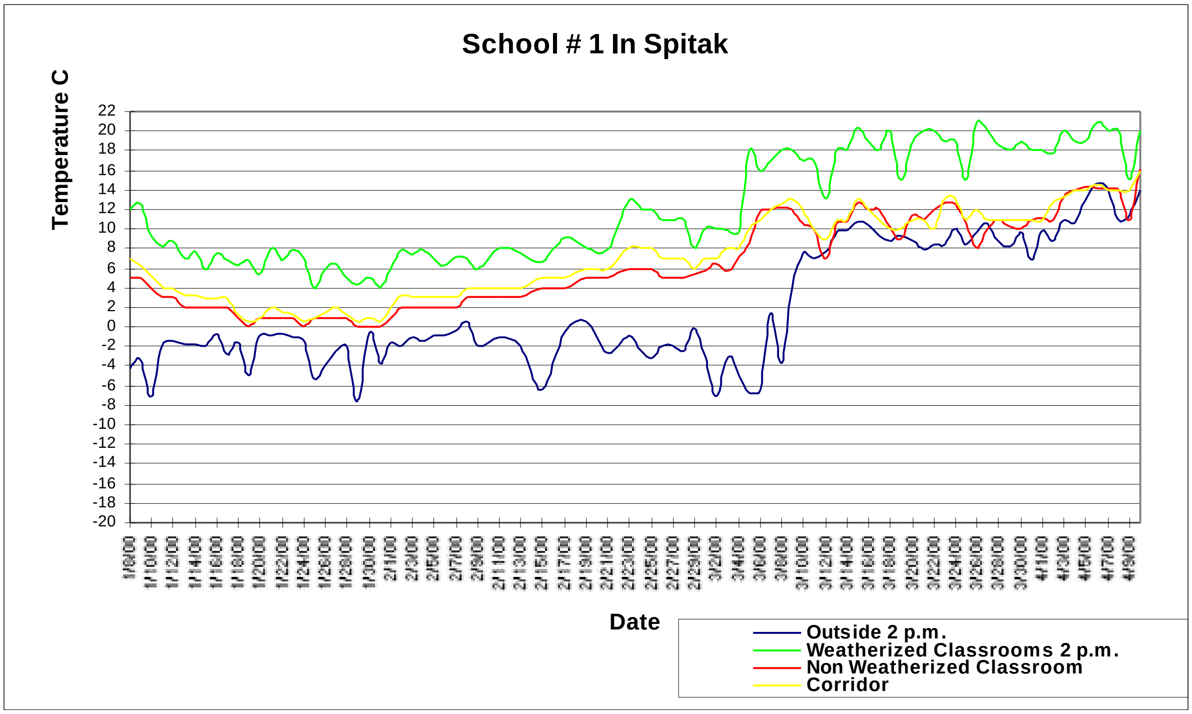


Figure 2.3
Heat Loss Reduction, Spitak School #1

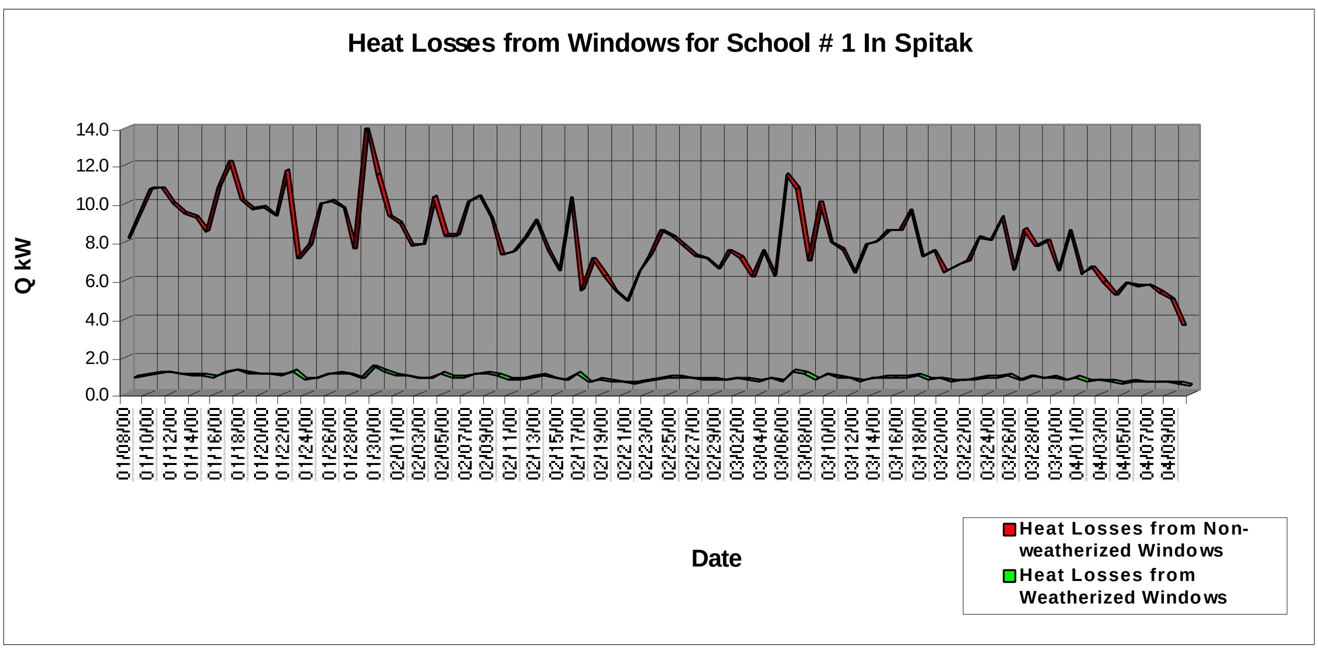
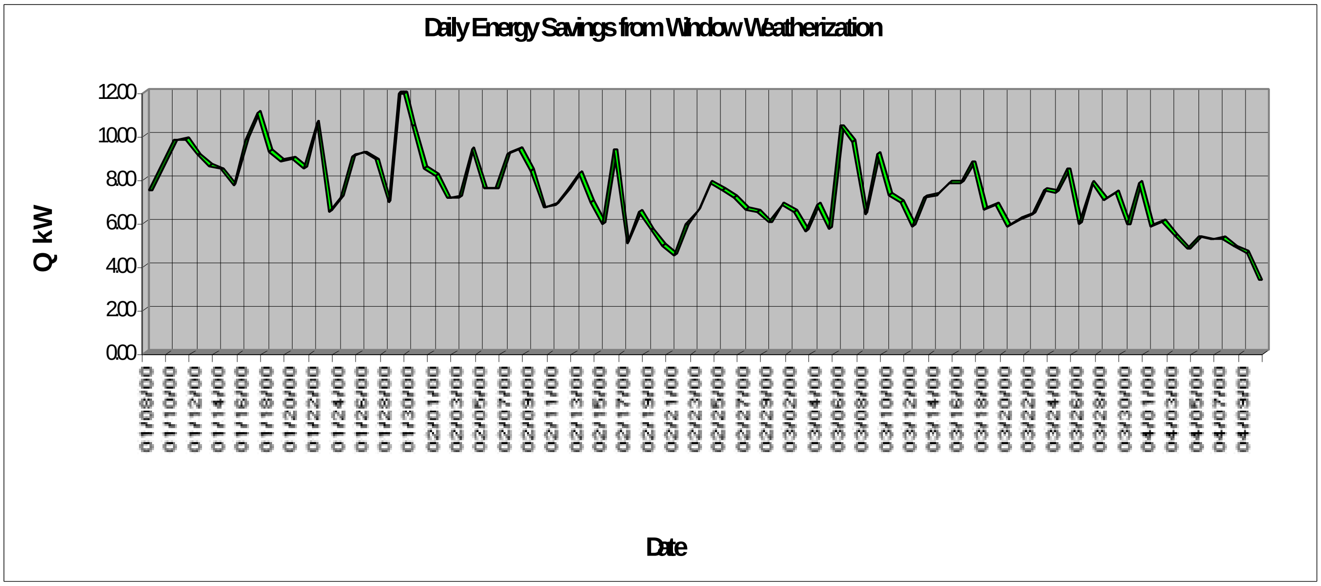


Figure 2.4
Energy Savings from Weatherization, School #1, Spitak



The graphs demonstrate the following results:

* Room temperature in the weatherized room is an average of 8^{o} C higher.
* Average infiltration air volume from 1 standard size window is reduced by weatherization from 15.1 m^3/h per window to 1.14 m^3/h per window
* Heat losses from infiltration were reduced by 95.5%

The monitoring period included 144 hours when the boiler was in operation (March 5 – April 10, 2000), and 2400 hours for monitoring the weatherization effects only. Based on the assumptions stated in the previous section (school would have been heated to a normal temperature, using electricity), the following energy and cost savings were calculated:

* Energy savings for monitoring period due to weatherization = 23,830 kWh
* Energy cost saving for monitoring period due to weatherization = $1192

<u>Theoretical</u>

Assuming a seasonal heating period of 4300 hours, and normal heating conditions, the following are calculated values of energy and cost savings due to weatherization and installation of an energy efficient boiler.

* Energy saving for the entire heating season due to weatherization – 57470 kWh
* Cost savings for the season due to weatherization – $2874
* Energy saving during heating period due to the replacement of electric heat by the high efficiency boiler –280080kWh
* Cost savings for heating period - $14,004
* Total cost savings during heating period due to weatherization and use of the boiler - $16,878
* Payback period = 2.1 heating seasons

2.3.2 School # 15 in Giumry

School #15 in Giumri was first constructed in 1967, and reconstructed in 1988 after the earthquake. Built of concrete blocks with tufa stone, it has the following characteristics:

Block #1: 3 floors; 36 rooms (26 classroom and 10 administrative offices)
Block #2: 2 floors; 14 rooms (13 classrooms and 1 administrative office)
Blocks of sport hall and corridor: 1 floor; 4 rooms (1 canteen, 3 toilets and cloak-rooms)

The school's operating capacity is 1110 students. The school's boiler house was shut down in 1996. Since then, the main sources of heating have been electric and kerosene space heaters, along with some wood stoves. A new gas-fired boiler with 94% efficiency was installed in the boiler house, and the school weatherized. The boiler was not installed prior to the end of the heating season therefore there are no actual measurements during the heating season while the boiler was in operation.

Monitoring Results

Figures 2.5 and 2.6 graphically depict the temperature of the outside air, weatherized and non-weatherized classrooms and corridor at School #15 in Giumry during the monitoring period. Figure 2.7 shows the difference in calculated heat losses between weatherized and non-weatherized rooms. Figure 2.8 shows the energy savings from the reduction of window heat loss as a result of weatherization.

Figure 2.5
6:00 A.M.Temperature Measurements in Giumri, School #15

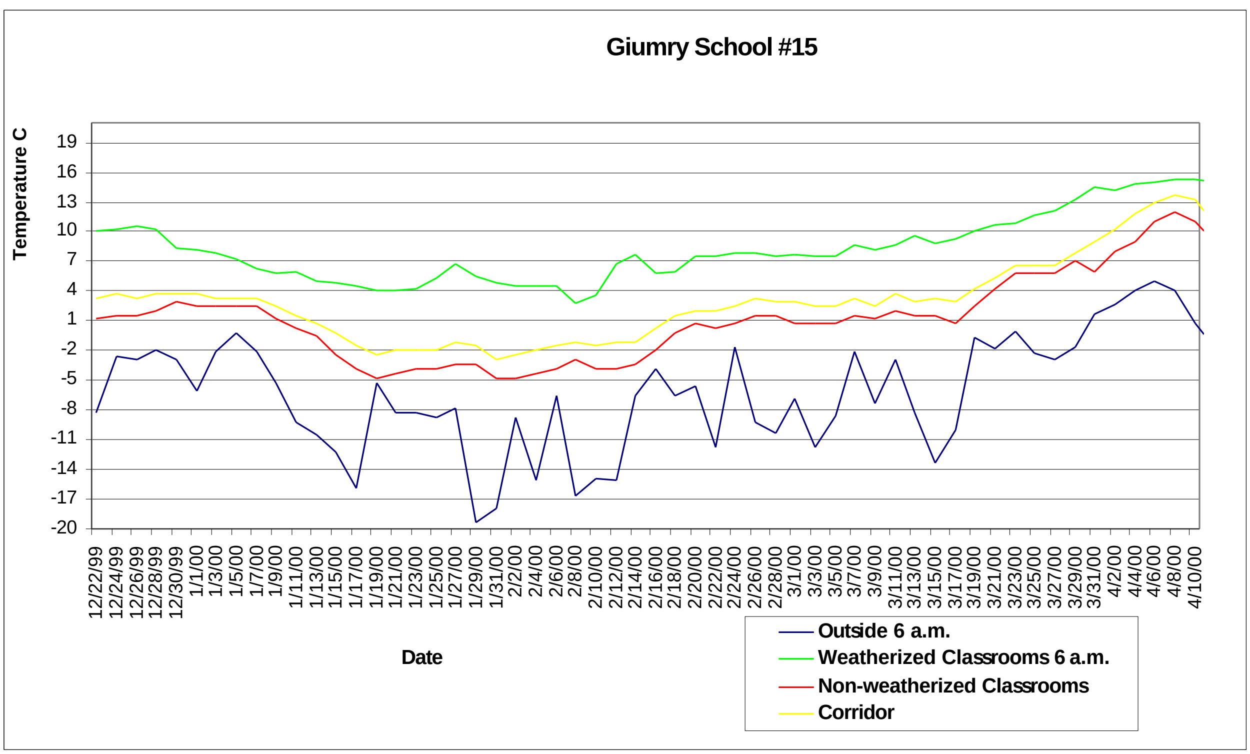


Figure 2.6
2:00 P.M. Temperature Measurements, Giumri School #15

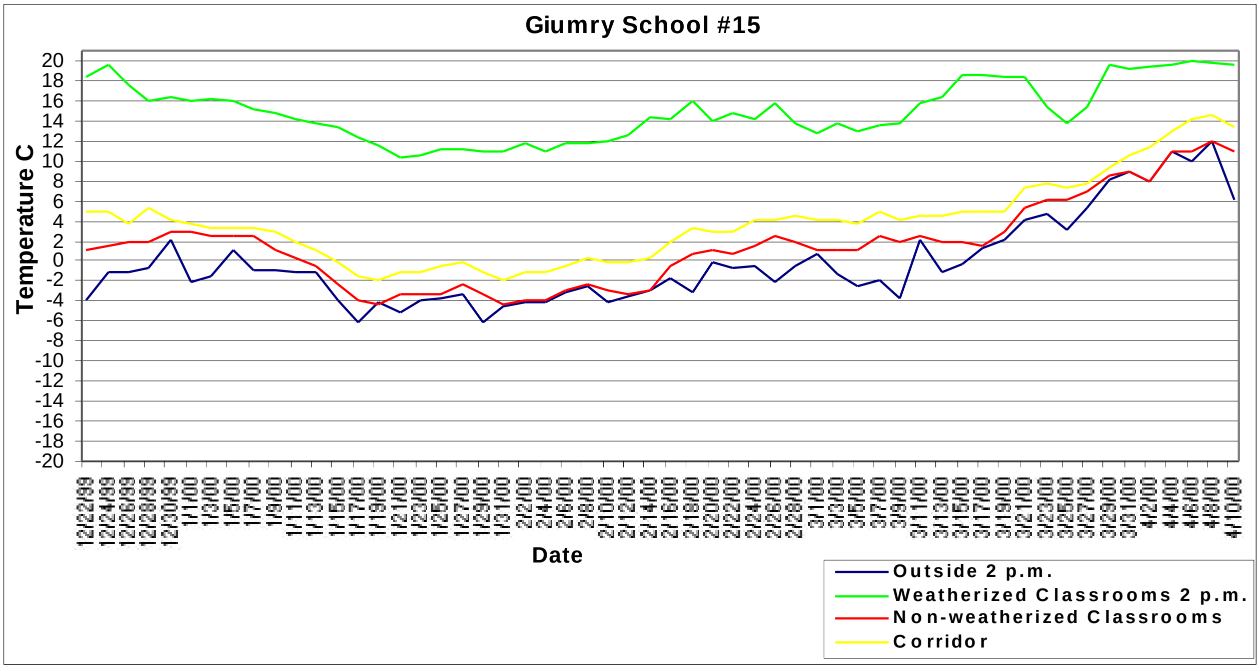


Figure 2.7
Heat Loss Reduction, Giumri School #15

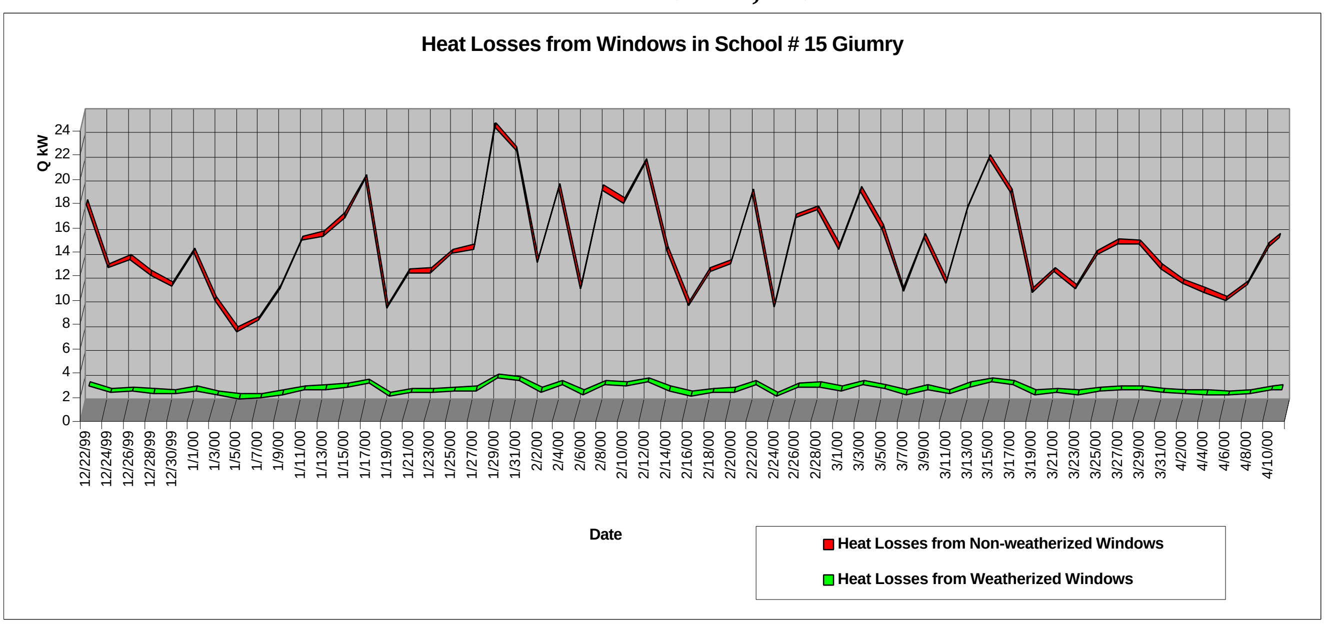
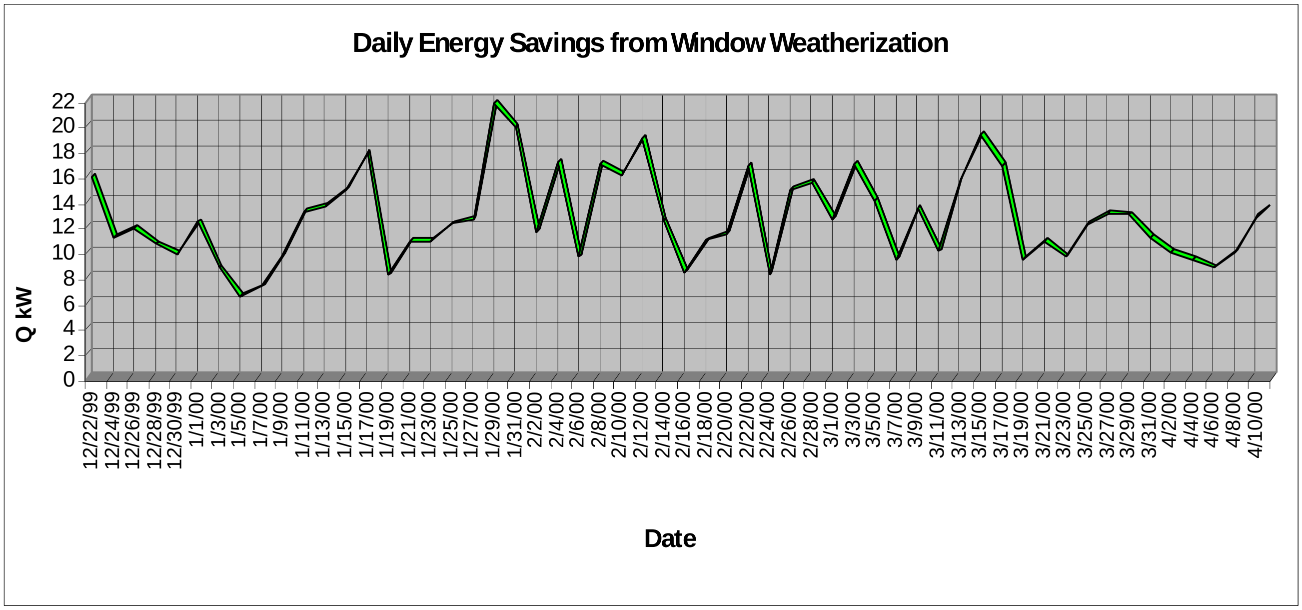


Figure 2.8



The graphs above demonstrate the following results from the project:

* Room temperature is higher by 10 –11 ^{0} C as a result of the weatherization.
* Average infiltration air volume from 1 standard size window was reduced from 15. 4 m^3/h per window to 1.4 m^3/h per window as a result of the weatherization;
* Heat losses from infiltration were reduced by 96%

The monitoring period for the weatherization was 2400 hours, during which time the following benefits can be calculated:

* Energy savings for the monitoring period due to weatherization – 45600 kWh
* Energy cost savings for the monitoring period due to weatherization - $2280

Theoretical

Given a normal temperature and a heating season of 4300 hours, the following are calculated energy and cost savings resulting from the weatherization and installation of a high efficiency boiler:

* Energy savings for the heating season due to weatherization = 106016 kW
* Cost savings for the heating season $5300
* Energy savings during the heating season due to the replacement of electric heating by the boiler = 430280kW
* Total cost savings during the heating season due to weatherization and use of the boiler - $26,815
* Payback period on the combined measures: one heating season

2.3.3 Shirvanzade School # 21 in Yerevan

School Shirvanzade is comprised of two blocks, and has the following physical characteristics:

Block #1 constructed in 1980 and block #2 in 1961: tufa stone blocks
Block #1: 5 floors, 38 rooms (23 classrooms, 6 teachers' offices, 3 halls, 1 canteen, 5 toilets)
Block #2: 5 floors, 36 rooms (30 classrooms, 2 administrative offices, 4 toilets)

The operating capacity of the school is 1190 students. The boiler house has been out of use since 1990. Since then, the main source of heating has been electric space heaters. A new gas-fired boiler with 94% efficiency was installed, however the new boiler was not put into operation prior to the termination of the heating season.

Monitoring Results

Figures 2.9 and 2.10 graphically depict the temperature of the outside air, weatherized and non-weatherized classrooms and corridor at the Shirvanzade School #21 in Yerevan during the monitoring period. *Figure* 2.11 shows the difference in calculated heat losses between weatherized and non-weatherized rooms. *Figure* 2.12 shows energy savings from the reduction of windows heat losses as a result of weatherization.

Figure 2.9
6:00 AM Temperature Measurements Shirvanzade School

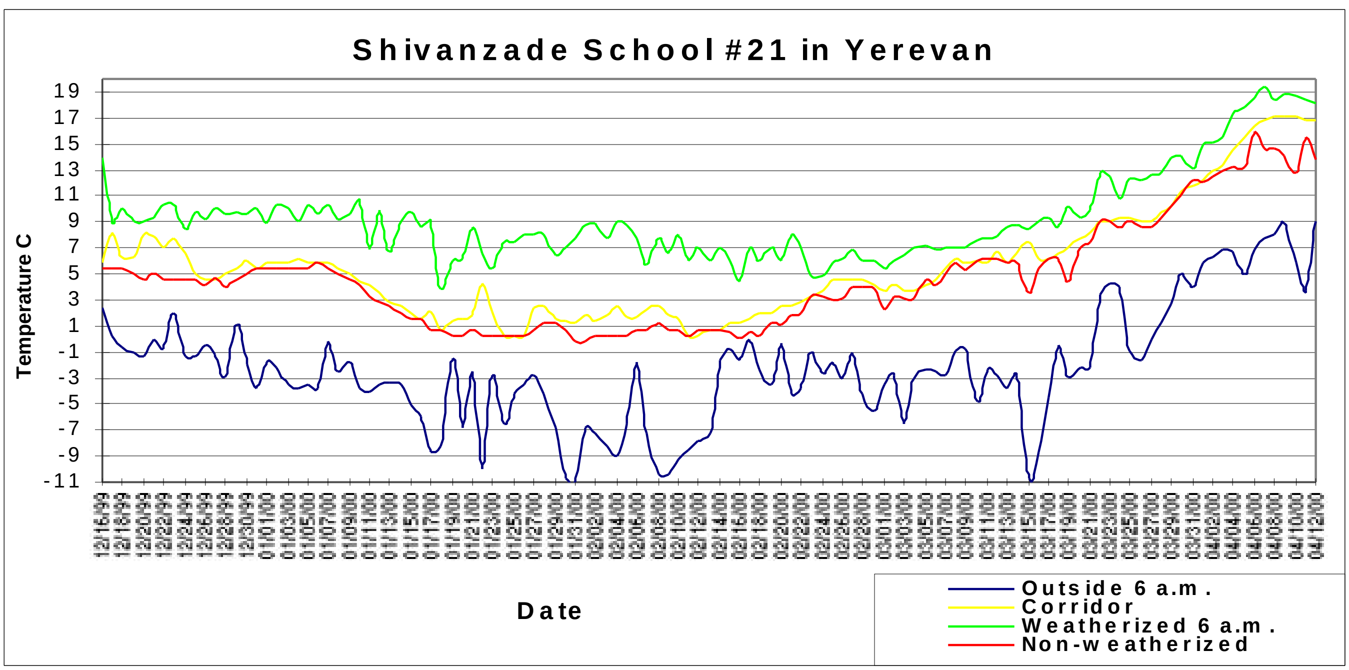


Figure 2.10
2:00 PM Temperature Measurements

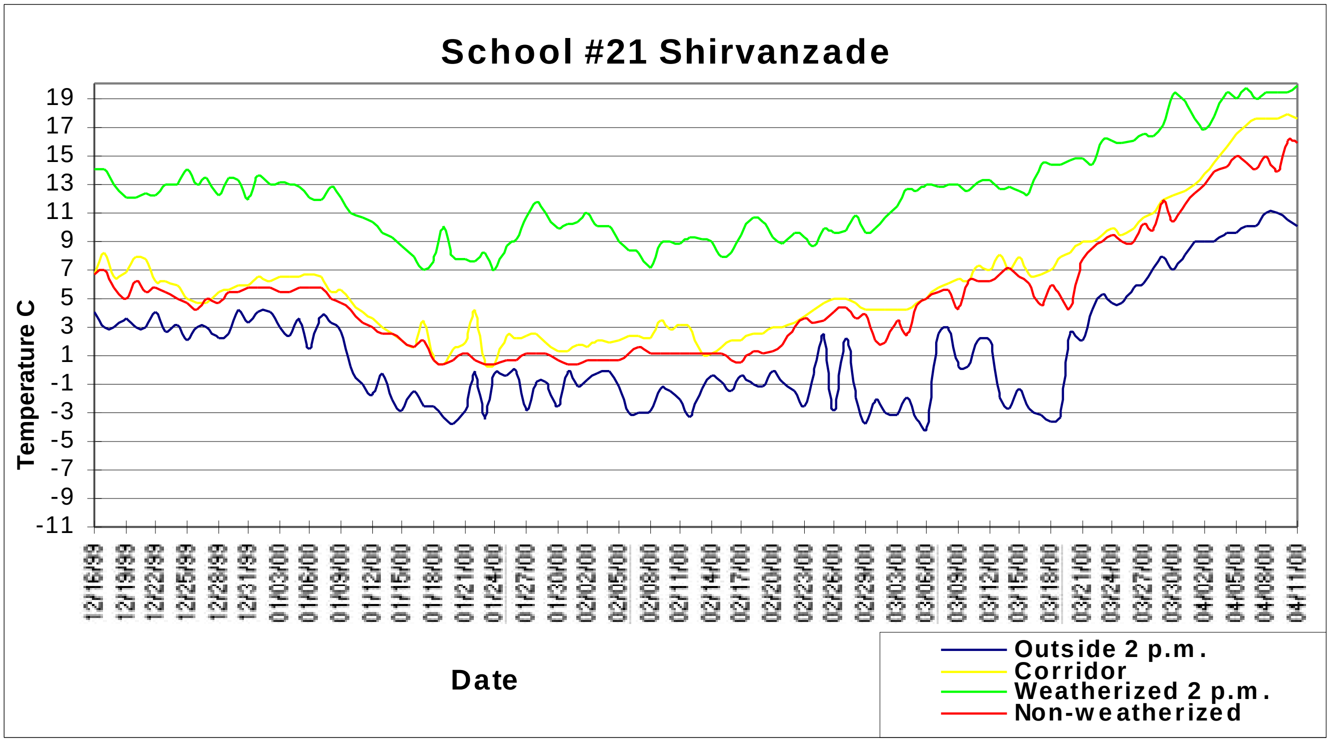


Figure 2.11
Heat Losses from Windows – Shrivanzade School

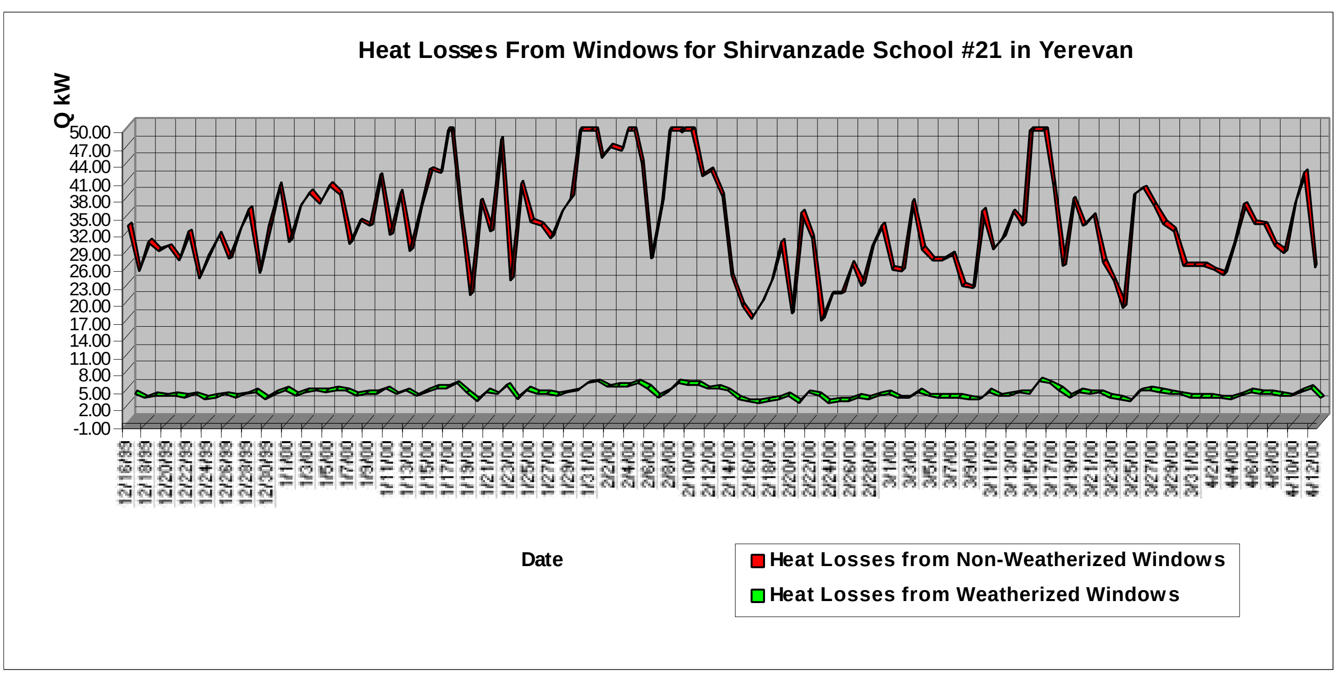
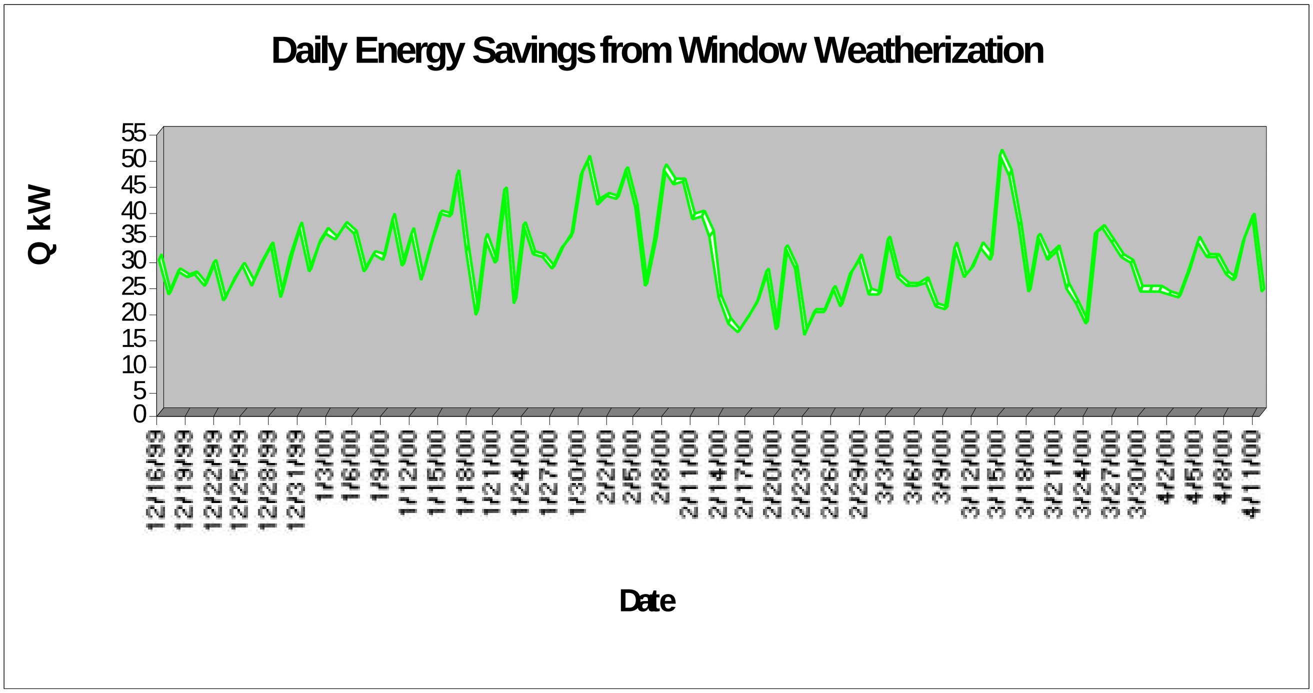


Figure 2.12
Daily Energy Savings – Shirvanzade School



The following conclusions are demonstrated by the above graphs:

* Temperature in the weatherized room is higher by 8-9 ^{0} C
* Average infiltration air volume from 1 standard size window is reduced from 13.5 m^3/h per window to 1.1 m^3/h per window;
* Heat losses from infiltration were reduced by 95 %

For the monitoring period of 2400 hours, the following energy and cost savings are calculated:
* Energy savings for the monitoring period due to weatherization – 95940kWh
* Energy cost savings for the monitoring period due to weatherization -$4797

<u>Theoretical</u>

With a normal heating season of 3500 hours, the following results are calculated:

* Energy savings for the heating season due to weatherization = 195326 kWh
* Cost savings = $9766
* Energy savings during heating period due to the replacement of electric heating by the boiler: 416400 kWh
* Cost savings for the heating period = $30586
* Payback period = 1.34 heating season

2.3.4 School # 132 in Yerevan

School #132 in Yerevan was constructed in 1967 from concrete blocks. There are five blocks of the school, with the following characteristics:

Block #1: four floors; 45 rooms (27 classrooms, 6 administrative rooms, 12 toilets)
Block # 2: 3 floors; 16 rooms (11 classrooms, 1 office, 4 toilets)
Block # 3: 3 floors; 30 rooms (22 classrooms, 2 offices, 6 toilets)
Sport hall block – 1floor; 2 sport halls with 4 coat rooms, 4 toilets, 3 offices, 2 classrooms.
Buffet block – 1 floor; large dining room, 5 kitchen rooms

The school's operating capacity is1792 students. The main source of heating prior to installing the new boiler was electricity since 1992,when the municipal district heating system was shut down. As part of the project, a new gas-fired boiler with 94% efficiency was installed.

Monitoring Results

Figures 2.13 and 2.14 graphically depict the temperature of the outside air, weatherized and non-weatherized classrooms and corridor at the School #132 in Yerevan during the monitoring period. *Figure* 2.15 shows the difference in calculated heat losses between weatherized and non-weatherized rooms. *Figure* 2.16 shows the energy savings from the reduction of windows heat losses as a result of weatherization.

Figure 2.13
6:00 AM Temperature Measurements, School #132 Yerevan

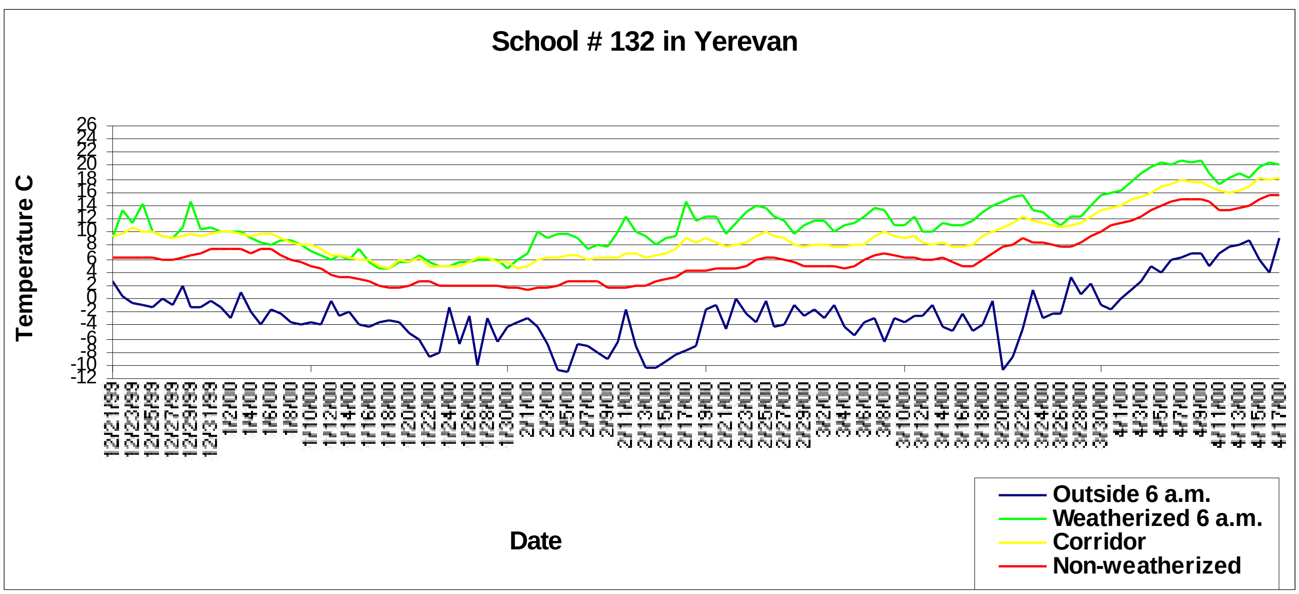


Figure 2.14
2:00 PM Temperature Measurements – School #132

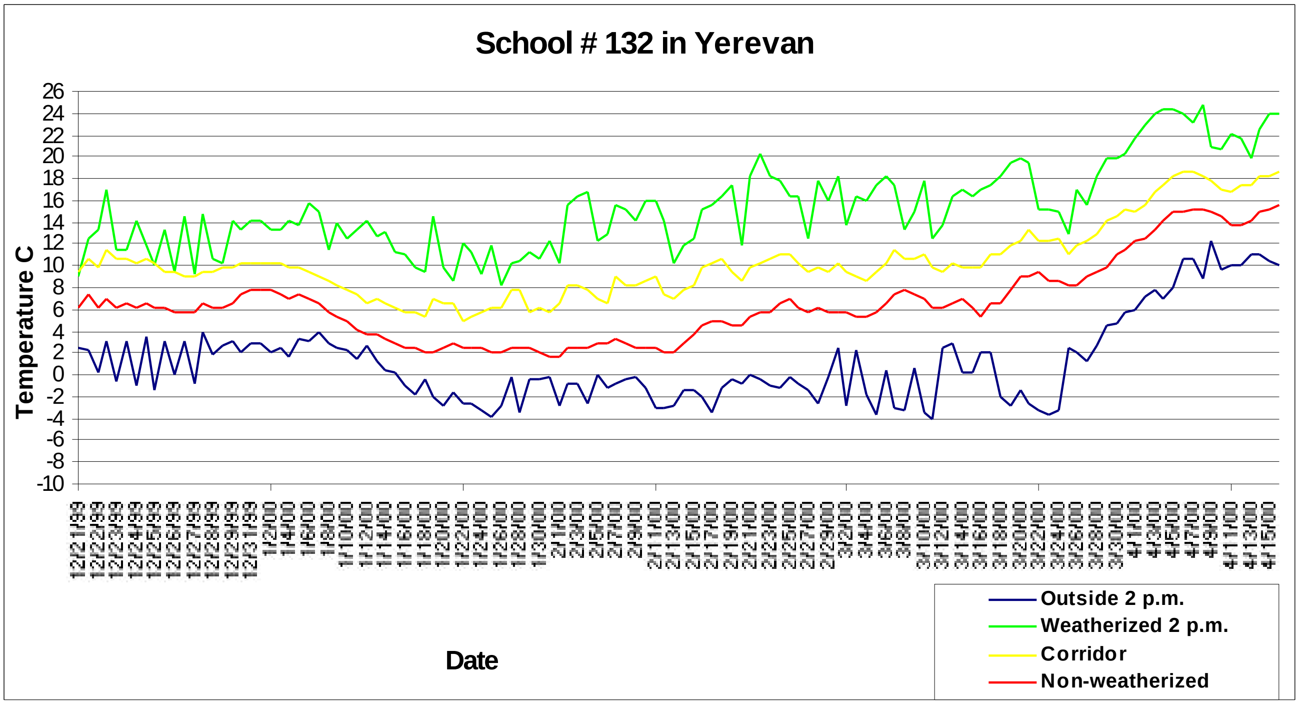


Figure 2.15
Heat Loss Reduction, School #132 Yerevan

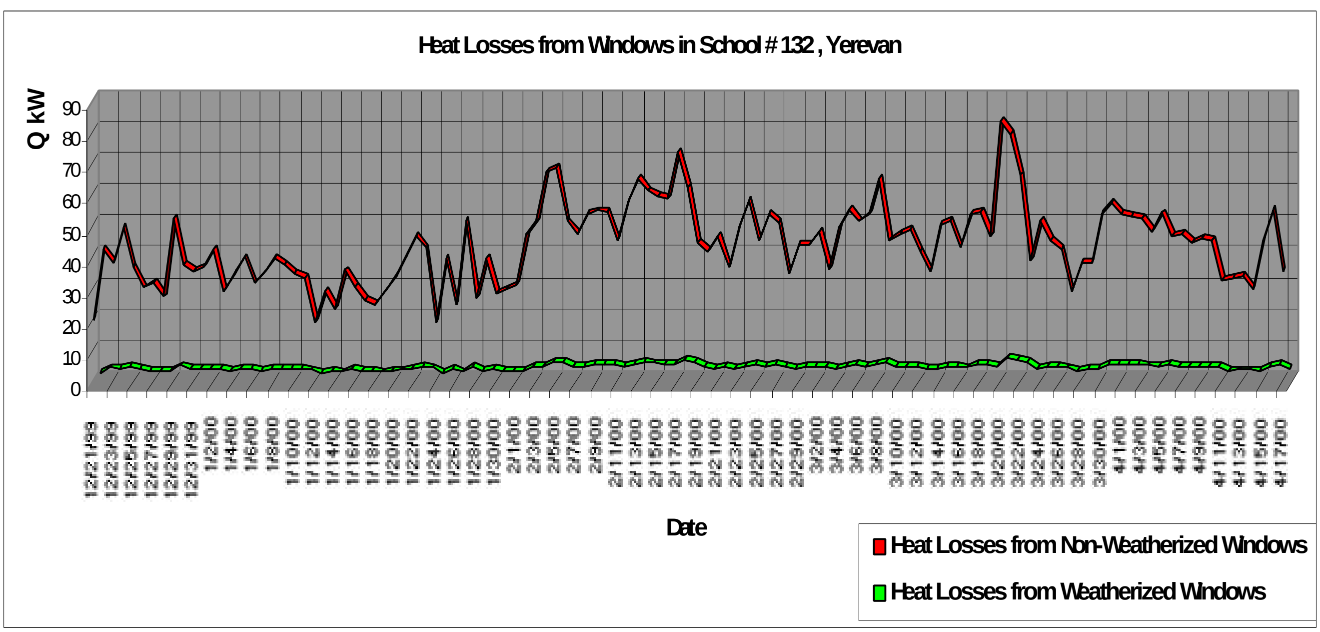
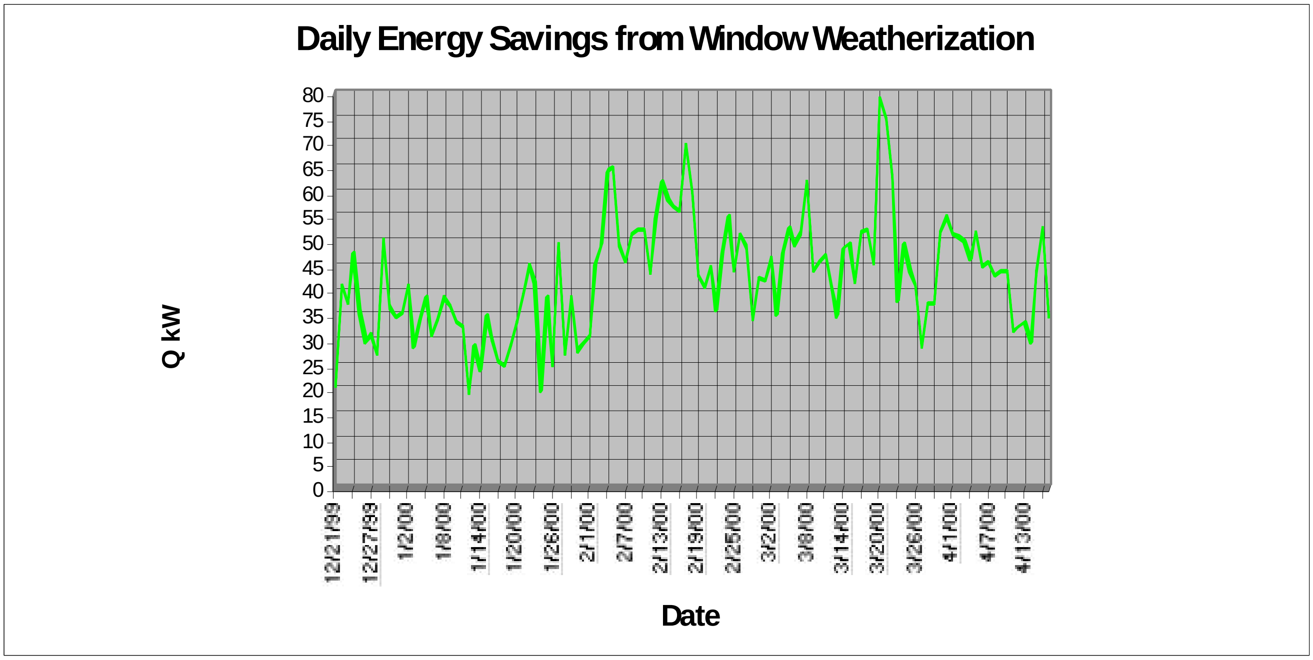


Figure 2.16
Daily Energy Savings – School #132



The graphs demonstrate the following results:

* Room temperature in the weatherized room is higher by 8-9 ^{0} C
* Average infiltration air volume is reduced from 13.9 m^3/h per window to 1.42 m^3/h per window;
* Heat losses from infiltration were reduced by 94 %.

For the monitoring period of 2400 hours, the following are calculated values assuming normal heating conditions:

* Energy savings for the monitoring period due to weatherization – 111066 kWh
* Energy cost savings for monitoring period due to weatherization - $5553

<u>Theoretical</u>

For the entire heating season of 3500 hours, the calculated values would be:

* Energy savings for the heating season due to weatherization =181256 kWh
* Cost savings = $9,063
* Energy savings for heating season due to the replacement of electric heating by the boiler-577600kWh
* Cost savings for the heating season = $28,880
* Total cost savings during the heating season due to weatherization and use of the boiler - $37,943
* Payback period = 1.73 heating seasons

3.0. Assessment of ESCO Outreach and Performance

Private sector participation in the energy sector is one of USAID's Intermediate Results that drive program design and funding. ESCO performance and the development of markets for ESCOs is a key aspect of the ESCO Development Program. The qualitative assessment included both a customer survey and an ESCO survey. These are summarized in this section.

3.1 Customer Survey

Selected participants at Schools #132 and Shirvanzade were asked their opinions of the ESCO Program results, and their responses are shown in Table 2.

Table 2.
Customer Survey

Weatherization Work ESCO	YES	NO	No Opinion
1. Has weatherization made your place more comfortable?	20=100%	0	0
2. Has weatherization saved energy?	20=100%	0	0
3. Is there less air coming through the windows and doors?	19=95%	0	1=5%
4. Is weatherization important to preserve the building?	19=95%	0	1=5%
5. For schools, which do you think is better – 0__centralized district heating, 16=80%__locally installed boiler?			4=20%
Heating System ESCO			
6. Did the workers perform high-quality work?	19=95%	0	1=5%
7. Did the workers use high-quality materials?	13=65%	1=5%	6=30%
8. Did the work significantly disrupt your activities?	4=20%	16=80%	0
9. Which type of heat do you prefer for heating the school: 0 elec 20=100% gas 0__kerosene 0__wood			0
10. Which type of heat do you think is least expensive but also provides adequate heat: _0_ elec. _20=100%_gas _0_ kerosene _0_ wood			0

As shown in the above table, the customer survey identified the following:

- 100% of the respondents agreed that weatherization really made their place more comfortable and contributed to energy saving.
- The majority of the consumers (95 %) admitted that there is less amount of infiltrated air coming through the windows and doors and that weatherization appears to be an important measure to preserve the building.
- On the question what, in their opinion, is better for schools - centralized district heating or locally installed boiler, 80% of the respondents favored the locally installed boiler rather than centralized district heating system.

- All of the respondents without exception named gas as the preferred type of heat, which costs less at the same time providing adequate heat.

3.2 ESCO Survey

Nine of the eleven ESCOs that participated in the ESCO Development program completed a survey asking them to assess their experiences. One (an NGO) was not asked to complete the survey since their main role was in training. Table 3 summarizes their responses to the survey. Appendix B contains their detailed comments by ESCO to the questions that ask for comments.

Table 3
Summarized Responses to ESCO Survey

A. Project's Impact on Your ESCO

	Yes	No	No opinion
1. Has participating in the ESCO Development Program assisted in the development of your company?	**9 = 100%**	0	0
2. Did you gain an increased ability to manage the business because of participating in the ESCO Project?	***9=100%***	0	0
3. Does your ESCO have an increased level of expertise in energy efficiency work because of participating in the ESCO Project?	**9=100%**	0	0
4. Does your ESCO have an improved ability to estimate costs accurately because of participating in the ESCO Project?	**9=100%**	0	0
5. Has your company made a profit on the work performed?	**9=100%**	0	0

B. Working Relationships

	Yes	No	No opinion
1. Was the AEAI/RMAr team good to work with? If no, please state what the problems were.	**9=100%**	0	0
2. Were they responsive to problems that may have developed during the program?	**9=100%**	0	0
3. Were the building administrators easy to work with?	**6=~66.6%**	0	3=~33.3%
4. Were the building administrators pleased with your work?	**7=~77.7%**	0	**2 = ~22.2%**
5. Were the teachers pleased with your work?	7=~77.7%	0	**2=~22.2%**

C. Future of ESCOs in Armenia

	Yes	**No**	No opinion
1. Has your ESCO performed energy efficiency activities since the ESCO Project work was completed?	6=~66.6%	**3=33.3%**	0
2. Does your ESCO expect to perform energy	8=~88.8%	0	**1=~11.1%**

efficiency activities in the next 3 months?			
3. Has your ESCO performed other energy efficiency work since the ESCO Project work was completed?	8=~88.8%	**1=~11.1%**	0
4. Will your ESCO be able to provide energy efficiency services for the next year?	**9=100%**	0	0
5. Is a market for energy services beginning to develop?	**9=100%**	0	0
6. Will there be a market for energy services without Government support?	2=~22.2%	**6=~66.6%**	1=~11.1%

3.3 ESCO Performance

For the most part, the ESCOs performed quite well on their tasks, as evidenced by the statements made in the customer survey and in the ESCO survey. No complaints were received regarding the quality of the work, although there were some complaints on the timing as the work was being done. Another measure of performance would be on how well the ESCOs did on adherence to the project schedule. In this area, there were delays that were substantially outside the control of the ESCOs. It was originally anticipated that the work would be completed in time for the winter of 1999-2000. However, due to the necessity to import high efficiency boilers from Germany, the program became quite delayed. Still, the work would have been completed in time for the some monitoring to take place during the winter, but then the air freight transportation became suddenly unavailable. Part of the heating system ended up being delivered by truck, when the program relied on air freight transportation being available for delivery of the burners.

4.0 ESCO Development Project Training Activities

The ESCO Development Project sponsored or participated in three training/workshop activities:

1. ESCO and Project Management Training Workshop (co-sponsored with the Armenian Chapter of the Association of Energy Engineers - ACAEE)
2. Seminar on Heating Strategy in Armenia (organized by ACAEE)
3. Heating System Policy and Strategy Workshop (co-sponsored with UNDP/GEF Climate Change Group of the Ministry of Environment)

4.1 ESCO and Project Management Training

The ESCO and Project Management Training workshop, held in July 1999, was organized primarily for the ESCOs that had participated in past USAID programs. The workshop attracted broad participation, with representatives from the ESCOs, the municipal heat supply department, the technical university, the Ministry of Energy, the gas supply company and USAID. In total, there were 25 participants in the workshop. The week-long course was held in conjunction with the Armenian Chapter of the Association of Energy Engineers (ACAEE), and qualified the participants for the Certified Energy Managers (CEM) certificate from AEE. Topics covered included ESCO markets, performance contracting, financial analysis of energy efficiency projects, energy efficiency technologies (HVAC, boiler efficiency, heat recovery, heat pumps), environmental considerations, and project management. A project management software package (Microsoft Project 98) was demonstrated and distributed to the ESCOs. An outline of the course and the list of participants are included in Appendix C.

At the conclusion of the course, participants were asked to evaluate the course content and make comments on future possibilities. Eighteen of the participants completed the course evaluation. Their responses have been summarized and reported in Table 4.

Table 4.
Participant Evaluation of
ESCO and Project Management Training Workshop

1. How appropriate were the topics covered in the ESCO workshop?

	Not Appropriate	Somewhat Appropriate	Very Appropriate
a. ESCO development		2 resp.	16 resp.
b. New energy efficiency technologies		3 resp.	15 resp.
c. Institutional issues		6 resp	12 resp.
d. Project management		3 resp.	15 resp.

2. For which topics you need further training.

ESCO development, ESCO international experience; Contract on Final Result	- 7
Energy Efficiency Technologies	- 5
Management Programs	- 2
Renewable Sources, Energy Audit	- 1
Heat Supply, Armenia's Government Energy Development Policy	- 1
Heat Pumps	- 1
Heating System, Ventilation, Conditioning	- 1

	Not useful	Somewhat Useful	Very useful
How useful were the discussions at the workshop?		4 resp.	14 resp.

	No	Yes
Did the workshop help you make new contacts in the energy field?		18 resp…

	Not useful	Somewhat Useful	Very useful
How useful were the printed handout materials?		3 resp	15 resp

	Not Satisfied	Somewhat Satisfied	Very Satisfied
Were you satisfied with the organization of the workshop such as conference room, registration, lunch, etc.?		1 resp.	17 resp.

7. Please write any other comments about this training workshop.

No Comments	- 10
Workshop conducted on a high level. Grateful for and welcome it	- 6
Pleased with the explanation and performance of different applications for energy audit	- 1
A part of the themes – good, a part – not necessary	- 1

4.2 ACAEE Seminar on Energy Efficiency

The ACAEE organized a seminar for energy sector personnel on energy efficiency options in Armenia. The seminar was attended by more than 50 people, from all organizations concerned with energy issues. Speakers included the World Bank representative, Mr.Owaisse Sadat; USAID Energy Officer, Michael Boyd; ACAEE Chapter President, Zohrab Melikyan and others. Ms. Worzala presented the audit results from the USAID School Heating Systems projects. The workshop was well-attended by representatives from various media also, and resulted in several television, radio and newspaper stories about the USAID project and energy efficiency.

4.3 Heating Systems Policy and Strategy Workshop

A two-day workshop on heating sector policy and strategy was organized with the UNDP/GEF Climate Change Group in the Ministry of Environment. This workshop brought together participants from all of the concerned sectors to discuss the elements that need to be worked out to formulate a heating sector strategy. The agenda and list of participants are included in Appendix D. The workshop used two models developed by Dr. Hameed Nezhad (STRUCTURE and DECIDE) to initiate the strategic planning process.

4.3.1 Key Issues Identification

The key issues identified in the workshop were divided into five main areas. After a lengthy discussion with the workshop participants, the following issues were identified for further investigation.

? ? **1. Technical Issues**

- Energy efficiency (generation, transmission, and distribution)
- System reliability
- Safety
- Suitable Infrastructure such as gas and hot water pipelines, metering, etc.
- Building energy efficiency
- System control
- System restart
- Water supply reliability
- Potential for hot water supply

2. Financial Issues

- Initial costs of the system (new or rehab.)
- O & M costs
- Profitability
- Tariff design and implementation
- Ease of Collection
- Funding possibility
- Financing costs
- Sovereign guarantees
- Financing feasibility
- Fuel cost
- Externality value
- Externality costs

3. Consumer Issues

- Income limitations
- Reliability
- Control
- Costs
- Convenience
- Awareness
- Possibilities of switching fuels and cost of such actions
- Consumer rights and obligations
- Arrearage
- Transparency

4. Legal / Political / Institutional Issues

- Energy supply reliability and security
- Availability of international funds
- Codes and standards
- Regulatory framework
    - for consumers and
    - for producers
- Investment incentives by government

5. Ecological / Environmental Issues

- Deforestation
    - Choice of fuel
    - Pollution

4.3.2 Analysis of Key Issues

Using STRUCTURE® software program developed by Dr. Hameed Nezhad, the following nine key issues were selected and analyzed. Figure 1 shows interdependence of these issues using STRUCTURE®.

Figure 4.1. Interdependence of Key Issues in Heating Sector in Armenia

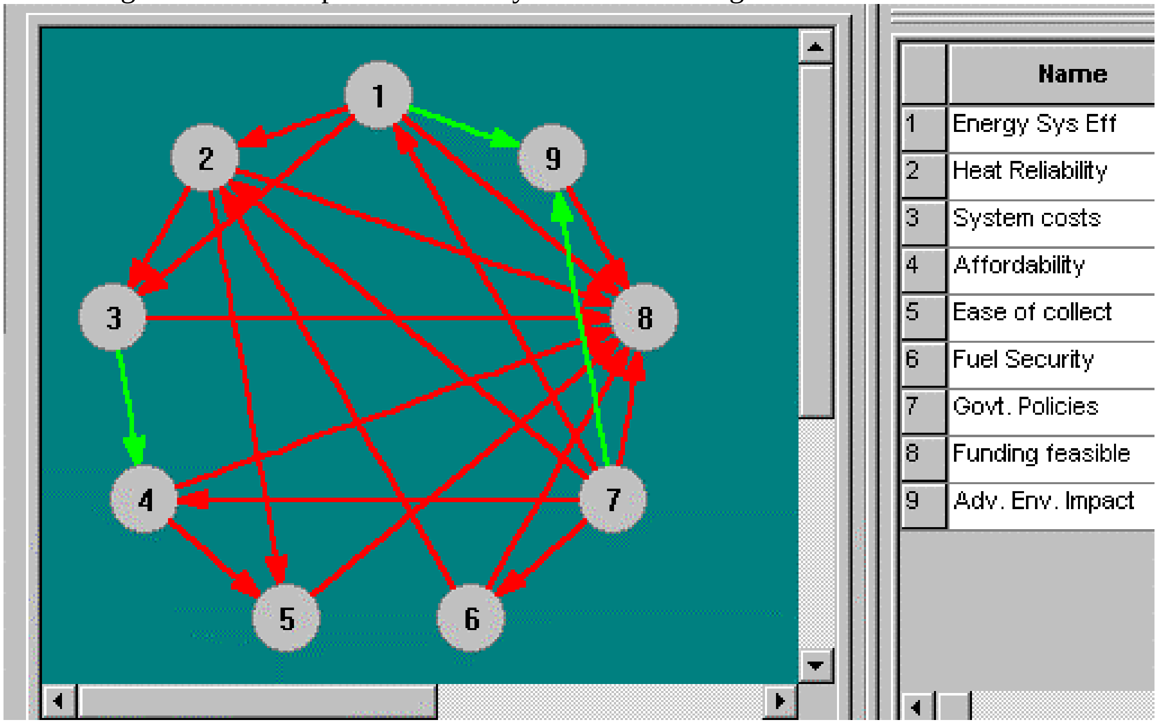


Figure 4.2. Level of Interdependence of the Key Issues in Heating Sector in Armenia

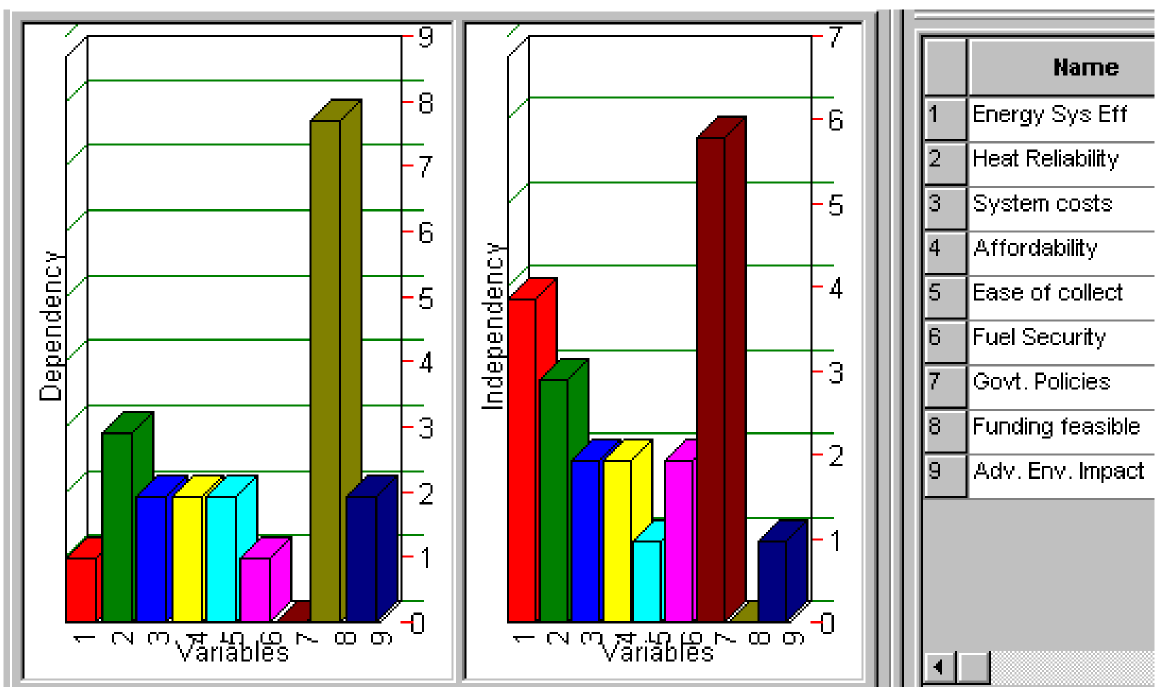


Figure 4.3. Impacts of Government Policies on Other Issues

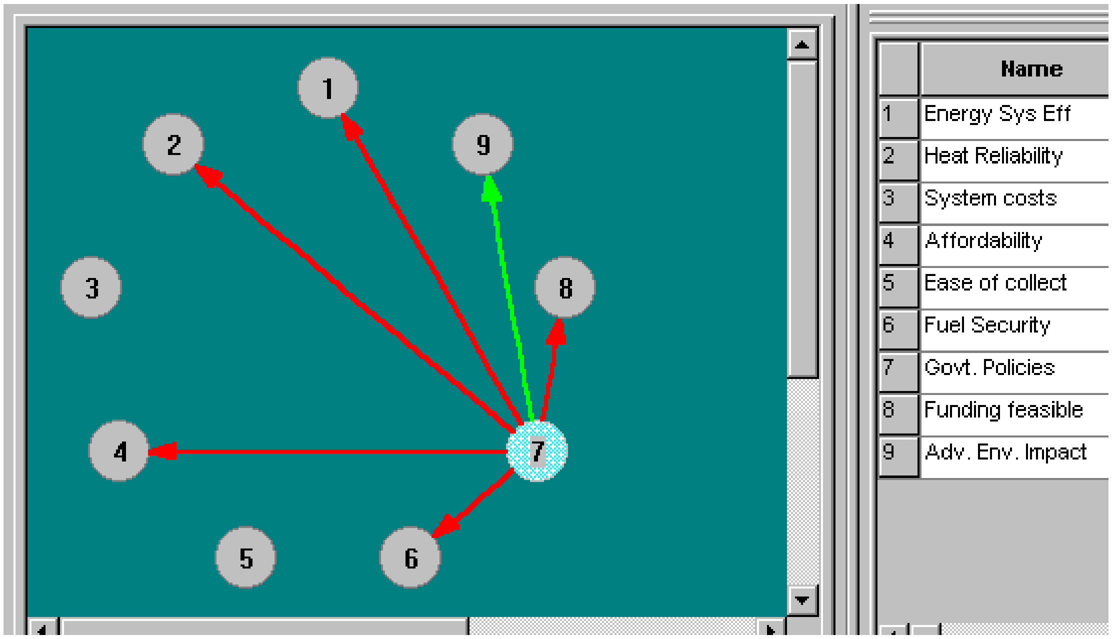
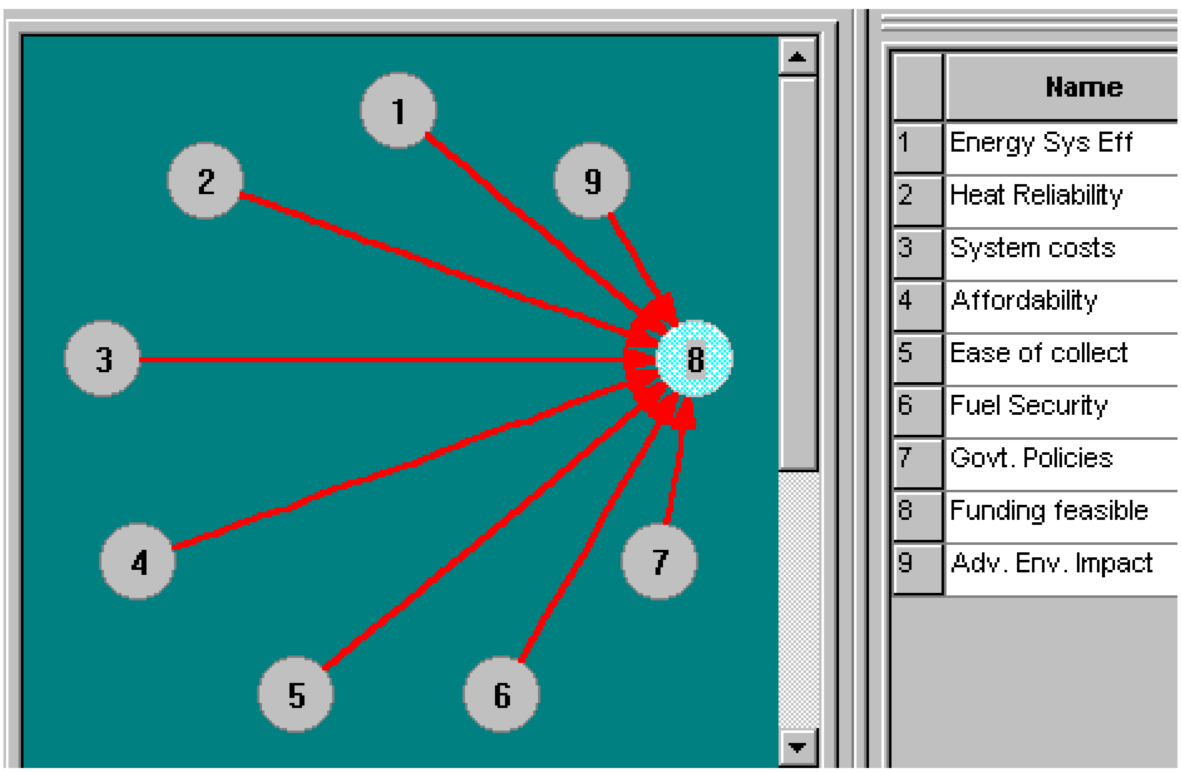


Figure 4.4. Dependence of Funding Feasibility on Other Issues



According to Figures 4.1, 4.2, and 4.3, the most "independent" variable (issue), which triggers other issues, is ***Government Policies***. Meaning that without appropriate government policies and regulatory reform, other issues will not be resolved. On the other hand, Figures 4.1, 4.2, and 4.4 show that all the identified issues must be resolved before funding by a multinational bank becomes feasible. Meaning that ***Funding Feasibility*** is the most "dependent" variable (issues).

4.3.3 Heating System Strategies

A systematic approach was used to identify and define the following key elements of a strategic plan for heating system development in Armenia.

A. Planning Horizon

Since complete restructuring of Armenia's heating system would take a long time, it was suggested to consider the following three planning periods:

- Short-Term Plan: 3 years or less
- Medium-Term Plan: 3 to 8 years
- Long-Term Plan: More than 8 years

Since the main purpose of the workshop was to develop long-term heating system strategies for Armenia, the focus of the discussion was primarily on the long-term strategies. However, the same process could be used to develop short-term and medium-term strategies.

B. Key Players in Development and Implementation of Heating System Strategies

The workshop participants identified the following key players:

- Consumer groups
    - Rural consumers
    - Urban-residential consumers
    - Urban-commercial consumers
    - Urban-institutional consumers
    - Urban-industrial consumers

- Central government
    - Ministry of Energy
    - Ministry of Finance
    - Ministry of Environment
    - Ministry of Urban Development
    - Ministry of Justice
    - Parliament

- Municipalities
- Multinational Banks and other funding agencies
- Energy Service Organizations including heating companies, ESCOs, fuel supply companies, and manufacturers/distributors of energy-related equipment.

C. Objectives of the Key Players

Based on the analysis of key issues, the following 10 objectives were identified. Table 1 shows how these objectives related to each key player.

Objectives:

1. Affordability
2. Reliability of heating system
3. Control of heating system

4. Potential for hot water supply
5. Funding feasibility
6. Adverse environmental impacts
7. Fuel supply security
8. Total system costs
9. Ease of bill collection
10. Appropriate government policies

Table 5. Key Players and their Objectives in Heating System Development

	Consumers	**Central Government**	**Municipalities**	**Multinational Banks**	**Energy Service Organizations**
Affordability	✓	✓	✓	✓	✓
Reliability	✓	✓	✓		✓
Control	✓				✓
Hot water	✓	✓	✓		✓
Funding		✓	✓		✓
Environment		✓	✓	✓	
Fuel Supply		✓	✓	✓	✓
System costs		✓	✓	✓	✓
Ease of collection		✓	✓	✓	✓
Government Policies			✓	✓	✓

D. Heating System Strategies

The following four broad strategies were selected for further analysis:

1. Large-scale centralized systems
2. Small-scale centralized systems
3. Location-based centralized systems
4. Decentralized systems

4.3.4. Prioritization of Key Players, Objectives and Heating System Strategies

Using the above information, the following strategic planning model was developed. DECIDE 2000®software program, developed by Dr. Hameed Nezhad, was used to develop the model and to prioritize the key players, their objectives, and heating system strategies. A copy of both software programs was distributed to the key participants at the workshop.

Figure 4.5. Strategic Planning Model for Heating System in Armenia

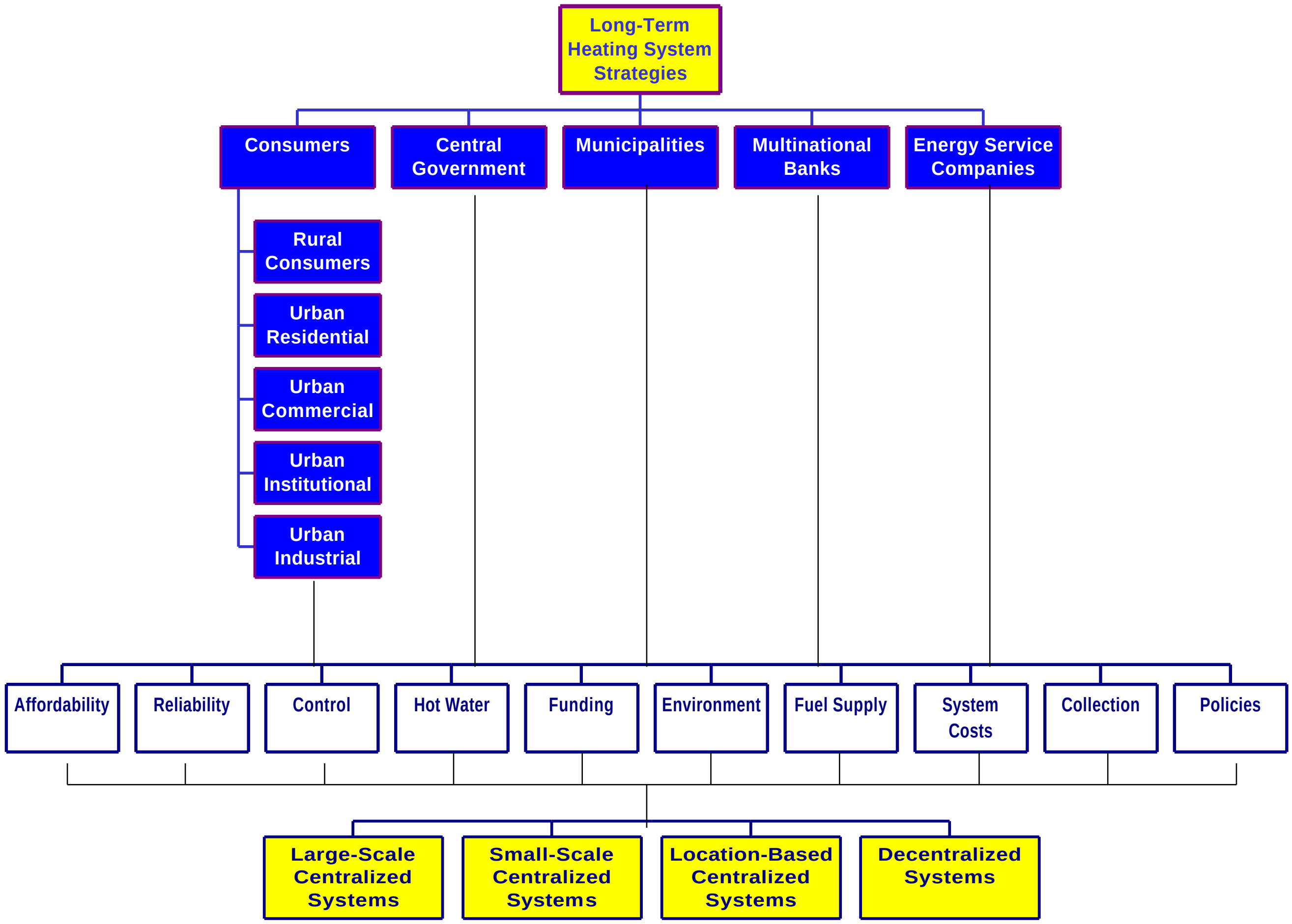


Figure 4.6. Priorities Weights of the Key Players

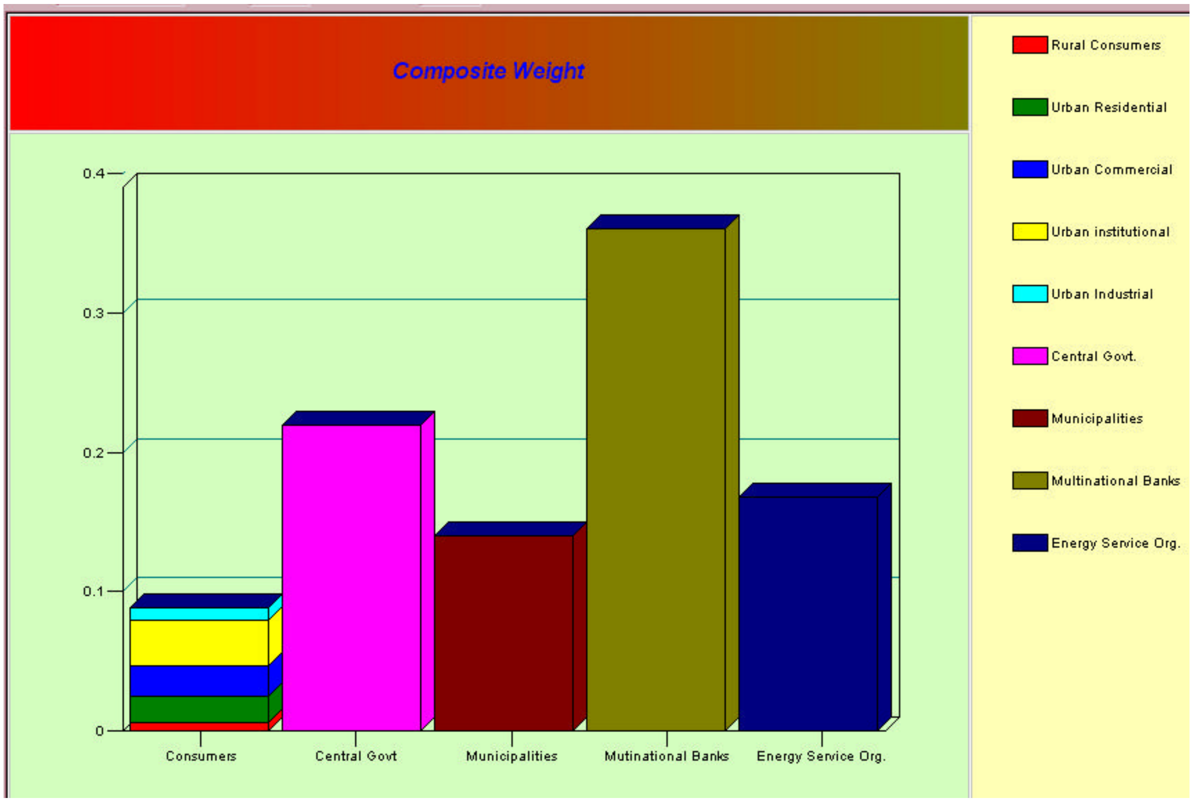
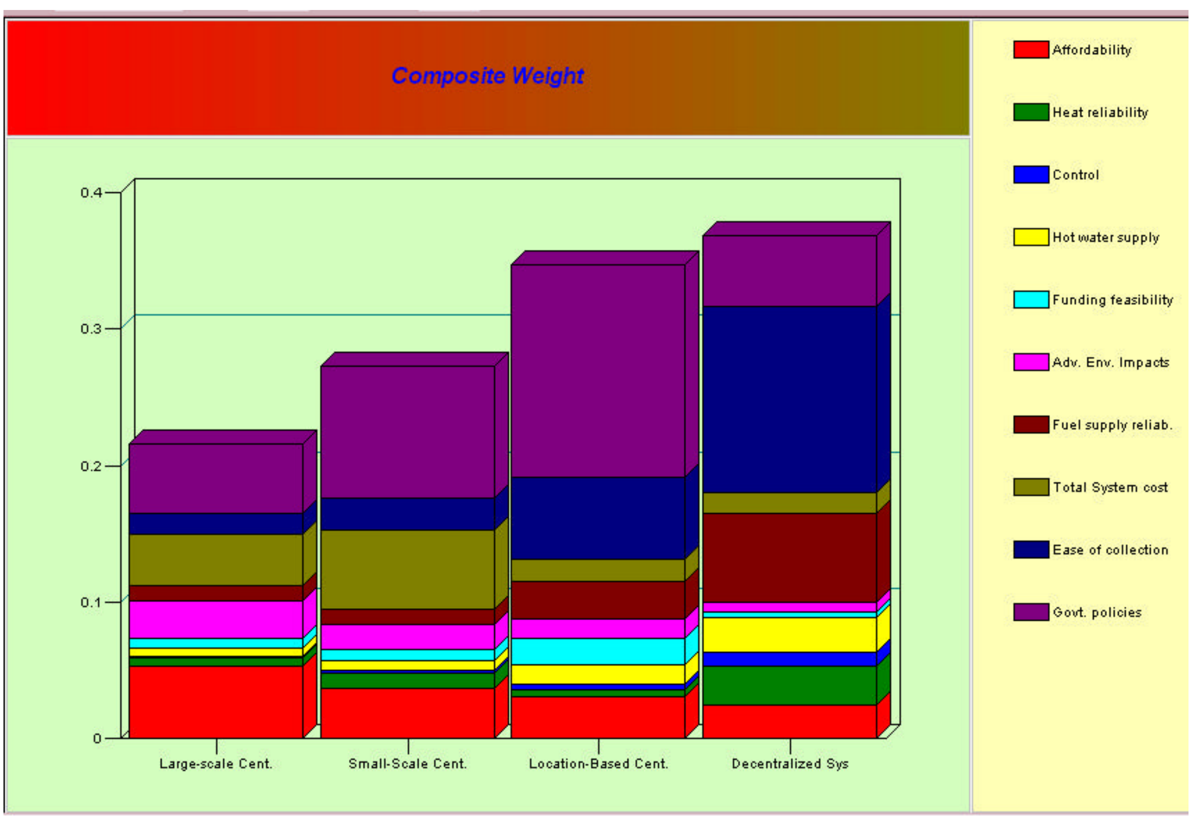


Figure 4.7. Priorities of Heating System Strategies and the Objectives



According to this preliminary analysis, Central Government and the Multinational Financial Institution and their objectives are the main driving forces behind heating system strategies. Figure 4.7 concludes that the most favored strategy (considering all the players and their objectives) is the decentralized heating system and the least favored one is the large-scale centralized systems. This is primarily due to government support and ease of bill collection.

4.3.5Workshop Conclusions and Recommendations

It should be emphasized that the above analysis and recommendations are based on two- day workshop and limited information. The main purpose of this workshop was to show the participants how to analyze the key issues surrounding the heating system development in Armenia systematically and consider all the key players and their priorities in heating system strategy development.

Recommendations:

1. Heating system in Armenia is a part of a larger system, which includes natural gas and other fuel supplies, water supply, electricity supply, not to mention the state of the economy. Thus, heating supply problems cannot be resolved in isolation.
2. We recommend creation of an independent organization which could provide Armenian government with reliable technical, financial, marketing, environmental, and sociocultural analysis of all the issues surrounding Armenian energy sector, including heating sector.
3. The model proposed in this report should be expanded and must include detailed qualitative and quantitative analysis of the key elements in the model.
4. The completed model should be shared with key government agencies and key consumer groups and energy service providers in order to get their perspectives of the proposed strategies. The model should be revised to meet their needs and requirements.
5. The leakiness of all building envelopes is a common problem in Armenia and other countries of the former Soviet Union. In the past fuel was cheap and building energy efficiency was not a high priority. The cost to improve building efficiency is very high, but a necessary cost for improving the heat supply system.
6. Rehabilitation of natural gas supply would take approximately 7 to 8 years. About 34% of gas distribution system is working now.

5.0 Expected Program Results

The Work Implementation Plan included Expected Results for each of the Subtasks in the ESCO Development Program. The Expected Results for each of the Subtasks, and the progress achieved towards the Expected Results is discussed in this section.

Subtask A: Development of a Portfolio of Integrated Weatherization/Heating System Projects
Expected Results:

- Final selection of a maximum of five sites (depending on the available budget and the work specified at each site) that will be included as a demonstration site.
- Energy audit report for each site.

Four sites were selected for energy audits, and for a demonstration project of integrated weatherization and heating systems. All four projects were completed, however only one was completed prior to the end of the heating season. This is due to unexpected difficulties in receiving imported boilers and burners, and to unexpected construction delays. The audit reports were completed and included in the "Weatherization and Heating Systems Projects Report".

Subtask B: Identification and Strengthening of Existing ESCOs
Expected Results:

- A minimum of five ESCOs will be recruited to participate in the ESCO Development training and bidding procedure.
- Training in project management, finance, performance contracting and some technical training will be provided to 15-20 persons from the participating ESCOs.

Eleven ESCOs participated in the ESCO Development Program, providing a variety of services. Training was provided to the ESCOs, as well as a broader audience through the training in performance contracting, heating systems strategy seminar and the energy efficiency seminar. The training provided to the ESCOs included project management, performance contracting and energy auditor certification training.

Subtask C: Weatherize Buildings/Improve Heating Systems Using Competitively Selected ESCOs
Expected Results:

- Successful completion of bidding process, with contract awards made to ESCOs for heating systems/weatherization work.
- Timely procurement of supplies and materials to complete the work at all sites
- Maximize procurement of local materials and equipment to be utilized in the program
- Installation work completed, functioning heating systems and high quality weatherization work.

The bidding process was completed with contract awards to the eleven ESCOs for the weatherization and heating systems work. The weatherization work was completed prior to the beginning of the 1999-2000 heating season. All of the heating systems projects were also completed, however not until the spring of 2000 due to delays in delivery of the boilers/burners that were outside of the Contractor's control. The streetlighting project that was recommended was not completed due to difficulties in collecting the cost share contribution from the schools. We had anticipated receiving approximately $10,000 in cost share from the schools, and the contribution by ArmRusGas of the construction of the gas line in Giumri. Only $3,500 was received from the schools. ArmRusGas failed to complete the gas line construction in a reasonable period of time, therefore the construction contract was awarded to a private company. All materials were procured locally with the exception of the boilers and burners.

Subtask D: Monitoring, Evaluation and Dissemination of Results

Expected Results:
- Design and implementation of a monitoring plan to evaluate program results.
- Workshop at each site to present results.
- Publicity in local media of successful results of program.

The monitoring plan was designed and implemented successfully. A workshop for boiler operators will be held in September, at the beginning of the 2000-2001 heating season. This training will be provided by the local supplier of the boilers. It was not provided prior to the completion of the contract because the schools have not yet hired boiler operators. Publicity in the media included:

1. Radio and television interviews about the program.
2. Newspaper stories about success of the program
3. Publicity by one of the schools in their own newsletter
4. Write-up of a success story for USAID'sWeb page
5. Television, newspaper and radio publicity with each of the workshops

6.0 Recommendations for Future Activities

This program has provided a very important contribution to the dialogue on decentralization vs. rehabilitation of Armenia's central heating systems. It has also provided solid experience to the ESCOs that participated in the program in what to expect in cutting a building off from the district heating system, and rehabilitation of the building's internal distribution network. Data on cost of energy efficient boilers, installation costs, and construction costs are also available. To support decision-making on energy efficiency strategy, the future rehabilitation and development of Armenia's heating sector strategy and to further develop the ESCOs, the following additional work should be considered by USAID:

1) Heating Systems Strategy Development and Pilot Projects: A momentum is building to address long-term solutions to heat supply in Armenia. The ESCO Development Project sponsored a workshop on heat supply strategy that brought together key stakeholders to discuss the issues. In addition, the World Bank will provide a grant for strategy development that will identify barriers and constraints to solving this problem. It is expected that the solution will be rather a diffuse strategy involving both public and private elements. Pilot projects, especially in the residential sector, will help to overcome barriers to private sector approaches.

2) Further ESCO Development – ESCOs can continue to provide weatherization and heating system installation services in the private sector, but can also expand their markets to other services, such as renewables, public information, billing and collection for heat services, and local financing options. Future activities in energy efficiency should utilize the services of existing ESCOs to expand upon their knowledge and experience base, as well as develop new ESCOs.

3) Support to the Armenian Chapter of Association of Energy Engineers (ACAEE) - The ACAEE has a large membership of over 70 energy professionals, but constantly struggles with ways to provide a forum for exchange of ideas and member services with little or no funding. ACAEE is an organization that is worthy of support so that it can continue its advocacy of energy efficiency and rational energy policies in the development of Armenia's energy future. Support to the Chapter could include English language training (so members can read the materials from the US); audit equipment to be loaned for a small fee to members and non-members; CEM training workshops for members; newsletter publication; other information dissemination; and office equipment such as a copier.

4) Energy Efficiency Education Program in Schools – Energy education in the schools could be a very cost-effective way of raising the awareness of the general population of how scarce and expensive energy resources can be conserved. Educating students and teachers is also important for maximizing the benefits of the energy efficient boiler installations in the schools. A curriculum could designed based on materials used in the US, and an advertising campaign could be based on promotional materials produced by the students.

5) Energy Efficiency Fund - Together with other donor organizations, USAID could create an energy efficiency fund that will be used to implement cost-effective energy efficiency projects. This could alleviate one of the major barriers in Armenia.

Appendix A
Energy Savings and Cost Calculations

- ## Energy Savings and Impacts on the School Buildings

Quantitative Results
To estimate the total quantitative economic impacts of the weatherization of windows and the use of high efficiency boiler for heating of school buildings, a data collection and analysis plan was developed. Data collection was performed over the winter 1999-2000. Temperature loggers were installed in the weatherized and non weatherized rooms of each school building for measuring inside and outside temperatures. Every 6 hours, data loggers recorded the momentum temperatures in the weatherized and non-weatherized control rooms at each of the locations. By means of special devices the quantity of infiltration air was measured twice a day in both weatherized and non-weatherized control rooms.
The goal of data collection during the monitoring period was to estimate the real energy and economic impacts of the weatherization-high efficiency boiler combination: 1. Determination of the average increase of temperature in weatherized rooms; 2. Energy savings for heating due to weatherization; 3. Energy cost savings for heating due to weatherization; 4. Energy cost savings for heating due to high efficiency boiler; 5. Determination of payback periods of the implemented energy efficiency measures.

- **ASSESSMENT OF ENERGY AND ECONOMIC CHARACTERISTICS AND COST EFFECTIVNESS OF COMBINED WEATHERIZATION - GAS BOILER PROJECTS FOR THE SCHOOLS BY MONITORING DATA**

THE RESULTS OF MONITORING

The following paragraphs represent the information related to the quantitative assessment activity. Data are presented for the four weatherized facilities and are followed by analytical and graphical representations of the weatherization and boiler implementation impacts. Energetic, economic and pay-back calculations for each school are represented in the following tables.

ANALYSIS OF RESULTS OF MONITORING
The comparison of average values of measured temperatures and infiltrated air quantities proves that the weatherization of windows significantly increases the inside temperatures and decreases the infiltration air flow by the following way:

1. School # 1 Spitak. $D\ t = tin.av.w.m.p - tin.av.n\text{-}w.m.p = 13{,}2\ ^0C – 6{,}6\ ^0C = 6{,}6\ ^oC$;.
$D\ V\ inf.av. = Vinf.av.\ n\text{-}w.m.p. - Vinf.av.w.m.p = 15.1 - 1.14 = 13{,}96$ m^3/h per window.

2. School #15 Giumry. $D\ t = tin.av.w.m.p - tin.av.n\text{-}w.m.p = 12{,}9\ ^0C - 1{,}51^0C = 11{,}39\ ^oC$;.
$D\ V\ inf.av. = Vinf.av.\ n\text{-}w.m.p. - Vinf.av.w.m.p = 15.4 - 1.4 = 14{,}0$ m^3/h per window.

3. School Shirvanzade Yerevan. $D\ t = tin.av.w.m.p - tin.av.n\text{-}w.m.p = 12{,}7\ ^0C - 5{,}7 = 7{,}0\ ^oC$;.
$D\ V\ inf.av. = Vinf.av.\ n\text{-}w.m.p. - Vinf.av.w.m.p = 13{,}5 - 1.1\ m^3/h$ m^2 $= 12{,}4$ m^3/h per window.

4. School # 132 Yerevan. $D\ t = tin.av.w.m.p - tin.av.n\text{-}w.m.p = 15{,}9\ ^0C – 7{,}57\ ^oC = 8{,}33\ ^oC$;.
$D\ V\ inf.av. = Vinf.av\ n\text{-}w.m.p. - Vinf.av.w.m.p = 13.9 - 1.42 = 12{,}48$ m^3/h per window.

School # 1 in Spitak

Building Characteristics
Constructed in 1998 (block #1) and 1999(block #2): Block #3 will be constructed in 2000: tufa stone blocks
Educational blocks - 2 floors / 36 rooms (20 classrooms, 10 administrative rooms, 6 toilets)
Sport hall block – 1floor / sport hall with 2 cloak-rooms
Operating capacity – 529 people in existing blocks with 300 more people being added to the block # 3
Main sources of heating were electricity and kerosene heaters.
New gas fired boiler with COP – 94% was installed .

Quantitative Results

Actual

Temperature in weatherized room is higher by 8^{o} C
tin.av.w.m.p. = 13,20 ^{0}C; tin.av.n-w.m.p = 6,6 ^{o}C; tout.av.m.p. = - 2,4 ^{0}C.
Average infiltration air volume from 1 standard size window
in non-weatherized rooms - Vinf.av. n-w.m.p. = 15.1 m^3/h per window;
Average infiltration air volume from 1 standard size window
in weatherized rooms - Vinf.av.w.m.p. = 1.14 m^3/h per window
Heat losses from infiltration were reduced by 95.5%
Monitoring period = 144 hours of boiler operation (March 5 – April 10, 2000) , 2400 hours for weathrization
Energy savings for monitoring period die to weatherization = 23830 kWh
Energy Cost saving for monitoring period due to weatherization = 1192$

Theoretical

Heating period – 4300 hours
Energy saving for heating period due to weatherization – 57470 kWh
Money saving – 2874$
Energy saving during heating period due to the replacement of electric heating by the boiler – 280080kWh
Money saving for heating period - $14004
Total money saving during heating period due to weatherization and use of the boiler - $ 16878
Payback period = 2,1 heating season

ASSESSMENT OF THE REAL IMPACTS OF WEATHERIZATION DURING THE MONITORING PERIOD FOR SCHOOL # 1 IN SPITAK

Using the above monitored data, the realistic values of the heat power for heating the infiltrated air from outside average temperatures to the levels of inside average temperatures for weatherized ***Qw,kW,*** and non-weatherized ***Qn.w., kW,*** rooms of all schools are calculated as follows.

For weatherized rooms:

Qw. = 1,14 x 125 x 1,01 x 1,3 x (13,2 + 2,4) / 3600 = 0,81 kW

For non-weatherized rooms:

Qn.w. = 15.1 x 125 x 1,01 x 1,3 x (13,2 + 2,4) / 3600 = 10,74 kW

Saved heat power *D**Q inf.av., kW,*** **due to weatherization:**

*D**Q inf.av. = 10,74 kW - 0,81 kW = 9,93kW***

The quantity of heat, ***DQ inf.m.p., kWh,*** **saved during the monitoring period**:

DQ inf.m.p. = 9,93 x 2400 = 23 830 kWh

The quantity of electricity, saved in existing electric heaters, during the monitoring period:

DQ inf.m.p. = 23 830 kWh

The cost of saved electricity during the monitoring period is:

D Ce = 23 830 kWh x 0,05 = $ 1192

ESTIMATION OF THE REAL IMPACTS OF THE USE OF HIGH EFFICIENCY GAS BOILER IN SCHOOL #1 SPITAK DURING THE MONITORING PERIOD

The estimated quantity of heat Qb, kWh, produced by the boiler during the monitoring period:

Qb = 2080 x 35 530 x 0,94 / 3600 = 19 297 kWh

The cost of consumed gas: **C_g = 102 x 2080 / 1000 = $ 212,2**

The estimated quantity of electricity needed for producing Q_b = 19 297 kWh, by electric heaters:

Q_b = 19 297 kWh

The cost of consumed electricity: **C_e = 0,05 x Q19 297 = $ 965**

Money, saved during the monitoring period, due to implementation of the boiler:

DC_b = $965 – 212,2 = $ 752,8

The specific value of saved money:

DC_s = 752,8 / 9594 x (13,2 + 2,4) = 0,0051 $ /$m^{3o}C$

The total cost of savings due to weatherization and use of boiler during the monitoring period:

T = $ 1192 + $ 752,8 = $1944,8

ASSESSMENT OF THE IMPACTS OF WEATHERIZATION DURING THE HEATING PERIOD IN STANDARD COMFORT CONDITIONS IN BUILDINGS

Volume of the building - 9594 m^3;
tout.av.h.p = -3^{o}C;
Number of windous-125;
Heating period - 4300h;
Kb = $31 140 -Cost of the boiler implementation project.
Kw+Kd = $4788+0=$4788 - Cost of weatherization project and new entrance doors.

The quantity of heat, ***$DQ_{inf.h.p.}$, kWh,*** saved during the heating period, due to weatherization, in standard comfort conditions, when the inside temperature is ***t_{in}*****=18^{o}C,** and outside average temperature for Spitak is tout.av.h.p = -3^{o}C:

$DQ_{inf.h.p.}$ = 13,96. x 125 x 1,01 x 1,3 x (18 + 3) x 4300 / 3600 = 57470 kWh

The quantity of saved electricity during the heating period due to weatherization:

$DQ_{inf.h.p}$ = 57470 kWh

The cost of saved electricity due to weatherization:

D $C_{e.w.}$ = 57 470 x 0,05 = $ 2874 per season,

The seasonal heating load of the whole weatherized building (according to the audit):

$Q_{h.p} = 359\ 020\ kWh,$

The seasonal quantity of saved electricity:

$Q_{h.p,} = 359\ 020\ kWh.$

The cost of saved electricity:

$C_{e.b.} = 359\ 020\ kWh\ \ x\ 0{,}05 = 17\ 951\ \$ / season,$

The quantity of gas, consumed by the boiler during the heating period:

$G_g = 359\ 020\ x\ 3600\ \ / 35\ 530\ \ x\ 0{,}94 = \ 38\ 699\ \ m^3 / season,$

The cost of gas, consumed by the boiler during the heating period:

$Cg = 38\ 699\ x\ 102 / 1000 = 3947\ \$ / season.$

The money saving due to the replacement of electric heating by the gas boiler:

$DC_b = 17\ 951 - 3947 = 14\ 004\ \$ / season.$

Total money saving during the heating period due to weatherization and use of the boiler:

$(DC_{e.w} + DC_b) = \ \$\ 2874 + 14\ 004\ \$ / season = \ \$\ 16878\ \ per\ season.$

Total capital investment for implementation of weatherization and gas boiler installation projects: K = Kw + Kb = $4788 + $31 140 = $ 35928.

The simple pay-back period of capital investments for weatherization and implementation of the boiler in Spitak school building:

$P_{BP} = K / (DC_{e.w} + DC_b) = \$35\ 928 / 16878\ \$/season = 2{,}1\ season.$

School # 15 in Giumry

Building Characteristics

Constructed in 1967. Reconstructed in 1988 after earthquake: concrete blocks with tufa stone
Block #1 – 3 floors / 36 rooms (26 classroom and 10 administrative offices)
Block #2 – 2 floors / 14 rooms (13 classrooms and 1 administrative office)
Blocks of sport hall and corridor – 1 floor / 4 rooms (1 canteen, 3 toilets and cloak-rooms)
Operating capacity - 1110 people
Boiler hose shut down in 1996. Main sources of heating were electricity and kerosene heaters.
New gas fired boiler with COP – %94 has been installed in boiler house.
The boiler hasn't been in use due to the termination of the heating season.

Quantitative Results

Actual

Temperature in weatherized room is higher by 10 –11 ^{0} C
tin.av.w.m.p. = 12,9 ^{0}C; tin.av.n-w.m.p = 1,51^{o}C; tout.av.m.p. = - 3,85 ^{0}C.
Average infiltration air volume from 1 standard size window
in non-weatherized rooms - Vinf.av. n-w.m.p. = 15. 4 m^3/h per window;
Average infiltration air volume from 1 standard size window
in weatherized rooms - Vinf.av.w.m.p. = 1.4 m^3/h per window;
Heat losses from infiltration were reduced by 96%
Monitoring period for weatherization = 2400 hours

Energy saving for monitoring period due to weatherization – 45600 kWh
Energy cost saving for monitoring period due to weatherization - $ 2280

Theoretical

Heating period = 4300 hours
Energy savings for heating period due to weatherization = 106016 kW
Money saving for heating period = $5300
Energy saving during heating period due to the replacement of electric heating by the boiler = 430280kW
Total money saving during heating period due to weatherization and use of the boiler -$ 26 815
Payback period = 1 heating season

ASSESSMENT OF THE REAL IMPACTS OF WEATHERIZATION DURING THE MONITORING PERIOD FOR SCHOOL # 15 IN GIUMRY

Using the above monitored data, the realistic values of the heat power for heating the infiltrated air from outside average temperatures to the levels of inside average temperatures for weatherized ***Qw,kW,*** and non-weatherized ***Qn.w., kW,*** rooms of all schools are calculated as follows.

For weatherized rooms:

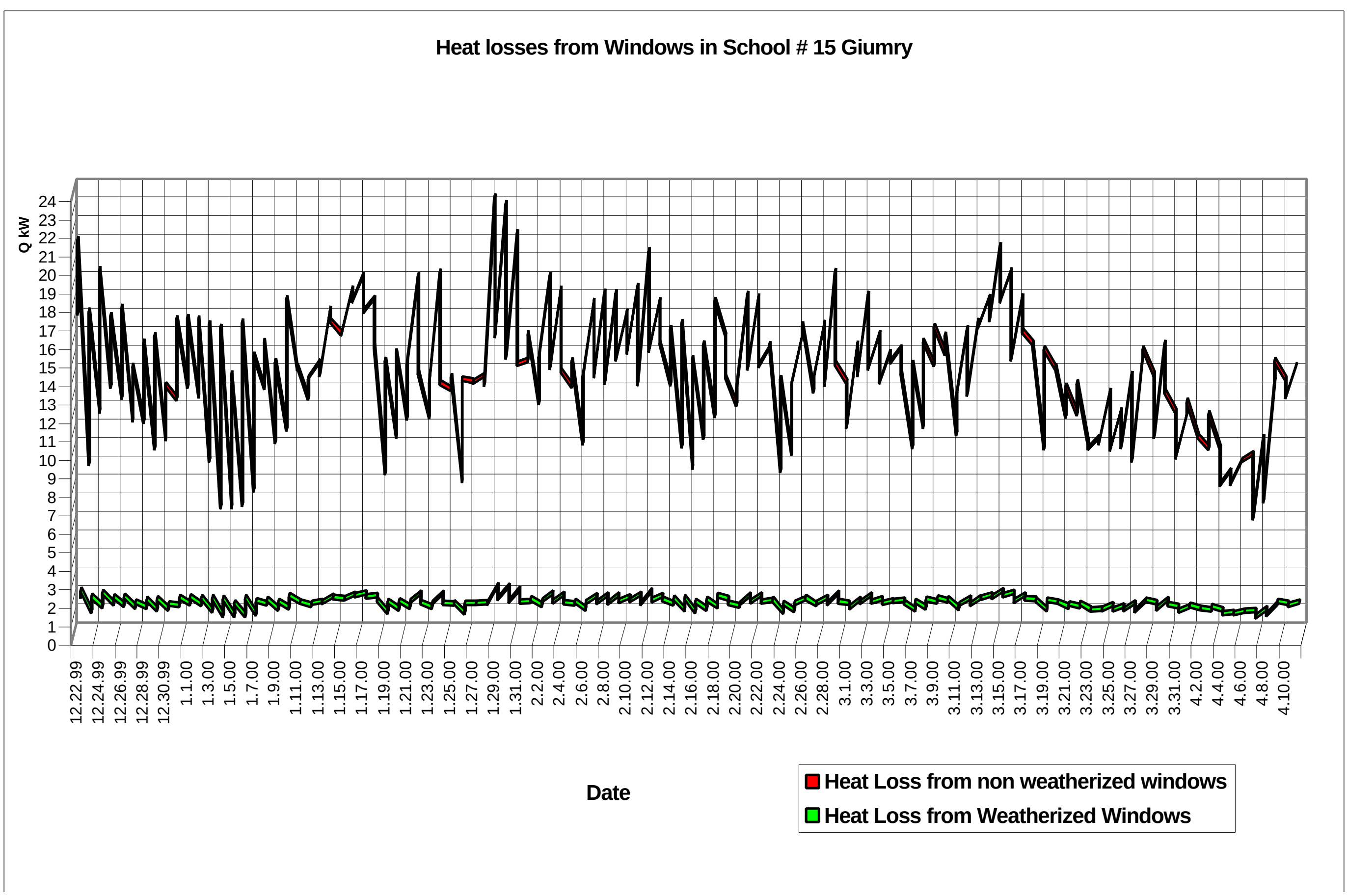
$$Qw. = 1,4 \times 222 \times 1,01 \times 1,3 \times (12,9 + 3,85) / 3600 = 1,9\ kW$$

For non-weatherized rooms:

$$Qn.w. = 15.4 \times 222 \times 1,01 \times 1,3 \times (12,9 + 3,85) / 3600 = 20,9\ kW$$

saved heat power *DQ inf.av., kW,* due to weatherization:

$$DQ\ inf.av. = 20,9\ kW - 1,9\ kW = 19,0\ kW$$



The quantity of heat, *DQ inf.m.p., kWh,* **saved during the monitoring period**:

$DQ\ inf.m.p. = 19{,}0 \times 2400 = 45\ 600\ kWh$

The quantity of electricity, saved in existing electric heaters, during the monitoring period:

$DQ\ inf.m.p. = 45\ 600\ kWh.$

The cost of saved electricity during the monitoring period is:

$D\ Ce = 45\ 600 \times 0{,}05 = \$\ 2280$

ESTIMATION OF THE REAL IMPACTS OF THE USE OF HIGH EFFICIENCY GAS BOILER IN SCHOOL #15 GIUMRI DURING THE MONITORING PERIOD

The specific value of saved money:

$DC_s = 0{,}0051\ \$/m^{3o}C$

Money, saved during the monitoring period, due to implementation of the boiler (in case of operation of new boiler in school #15 Giumri having volume 14 490 m^3 and ***tin.av.w.m.p – tout.av.m.p. = 16,75 ºC):***

$DC_{s.i} = 0{,}0051\ \$/m^{3o}C \times 14\ 490\ m^3 \times 16{,}75\ {}^oC = \$\ 1238$

The total cost of savings due to weatherization and use of boiler during the monitoring period:

$T = \$\ 2280 + \$\ 1238 = \$\ 3518$

ASSESSMENT OF THE IMPACTS OF WEATHERIZATION DURING THE HEATING PERIOD IN STANDARD COMFORT CONDITIONS IN BUILDINGS

tout.av.h.p = -3,5ºC;
Volume of the building – 14 490m^3;
Heating period - 4350h;
Number of windows-222;
Kw+Kd = $8049+4500=$12 549- Cost of weatherization project and new entrance doors installation;
Kb = $ 15 198.Cost of the boiler implementation project

The quantity of heat, $DQ_{inf.h.p.}$, ***kWh,*** saved during the heating period, due to weatherization, in standard comfort conditions, when the inside temperature is t_{in}**=18ºC,** and outside average temperature for Giumri is tout.av.h.p = -3,5ºC:

$DQ_{inf.h.p.} = 14{,}0 \times 222 \times 1{,}01 \times 1{,}3 \times (18 + 3{,}5) \times 4350 / 3600 = 106\ 016\ kWh$

The quantity of saved electricity during the heating period due to weatherization:

$DQ_{inf.h.p} = 106\ 016\ kWh$

The cost of saved electricity due to weatherization:

$D\ C_{e.w.} = 106\ 016\ kWh \times 0{,}05 = \$\ 5301$ ***per season,***

The seasonal heating load of whole weatherized building (according to the audit):

$Q_{h.p} = 551\ 565\ kWh,$

The seasonal quantity of saved electricity:

$$Q_{h.p,} = 551\ 565\ kWh\ .$$

The cost of saved electricity:

$$C_{e.b.} = 551\ 565\ kWh\ \times 0{,}05 = 27\ 578\ \$ / season,$$

The quantity of gas, consumed by the boiler during the heating period:

$$G_g = 551\ 565 kWh\ \times 3600\ / 35\ 530\ \times 0{,}94 = 59\ 453\ m^3 / season,$$

The cost of gas, consumed by the boiler during the heating period:

$$Cg = 59\ 453\ m^3 / season\ \times 102 / 1000 = 6064\ \$ / season.$$

The money saving due to replacement of electric heating by gas boiler:

$$DC_b = \$27\ 578 – \$6064 = 21\ 514\ \$ / season.$$

Total money saving during the heating period due to weatherization and use of the boiler:

$$(DC_{e.w} + DC_b) = \$\ 5301\ \$ / season + 21\ 514\ \$ / season = \$26815\ per\ season.$$

Total capital investment for implementation of weatherization and gas boiler installation projects: K = (Kw +Kd) + Kb = $12 549 + $ 15 198 = $ 27747

The simple pay-back period of capital investments for weatherization and implementation of the boiler in the Spitak school building:

$$P_{BP} = K / (DC_{e.w} + DC_b) = \$27\ 747 / 26815\ \$/season = 1\ season.$$

Shirvanzade School # 21 in Yerevan

Building Characteristics

Block #1 constructed in 1980 and block #2 in 1961: tufa stone blocks
Block #1 – 5 floors / 38 rooms (23 classrooms, 6 teachers' offices, 3 halls, 1 canteen, 5 toilets)
Block #2 – 5 floors / 36 rooms (30 classrooms, 2 administrative offices, 4 toilets)
Walls - tufa stone blocks
Windows – double glazed standard size.
Number of windows - 667
Volume of the building - 24960 m^3
Operating capacity – 1190 people
Boiler house is out of use since 1990.
Main sources of heating were electric heaters.
New gas fired boiler with COP = % 94 was installed
The new boiler hasn't been in use due to the termination of the heating season.

Quantitative Results

Actual

Temperature in weatherized room is higher by 8-9 ^{0} C
tin.av.w.m.p. = 12,7 ^{0}C; tin.av.n-w.m.p = 5,7 ^{o}C; tout.av.m.p. = - 0,55 ^{0}C.
Average infiltration air volume Average infiltration air volume from 1 standard size window in non-weatherized rooms - Vinf.av. n-w.m.p. = 13,5 m^3/h per window;
Average infiltration air volume from 1 standard size window in weatherized rooms - Vinf.av.w.m.p. = 1,1 m^3/h per window;.
Heat losses from infiltration were reduced by 95 %
Monitoring period = 2400 hours
Energy saving for monitoring period due to weatherization – 95940kWh

Energy cost saving for monitoring period due to weatherization -$ 4797

Theoretical

Heating period = 3500 hours
Energy savings for heating period due to weatherization = 195326 kWh
Money saving = $9766
Energy saving during heating period due to the replacement of electric heating by the boiler - 416400 kWh
Money saving for heating period = $ 30586
Payback period = 1,34 heating season

ASSESSMENT OF REAL IMPACTS OF WEATHERIZATION DURING THE MONITORING PERIOD

Using the above monitored data, the realistic values of heat power for heating the infiltrated air from outside average temperatures to the levels of inside average temperatures for weatherized ***Qw,kW,*** and non-weatherized ***Qn.w., kW,*** rooms of all schools are calculated.

For weatherized rooms:

$$Qw. = 1,1 \times 667 \times 1,01 \times 1,3 \times (12,7 + 0,55) / 3600 = 3,54\ kW$$

For non-weatherized rooms:

$$Qn.w. = 13.5 \times 667 \times 1,01 \times 1,3 \times (12,7 + 0,55) / 3600 = 43,51\ kW$$

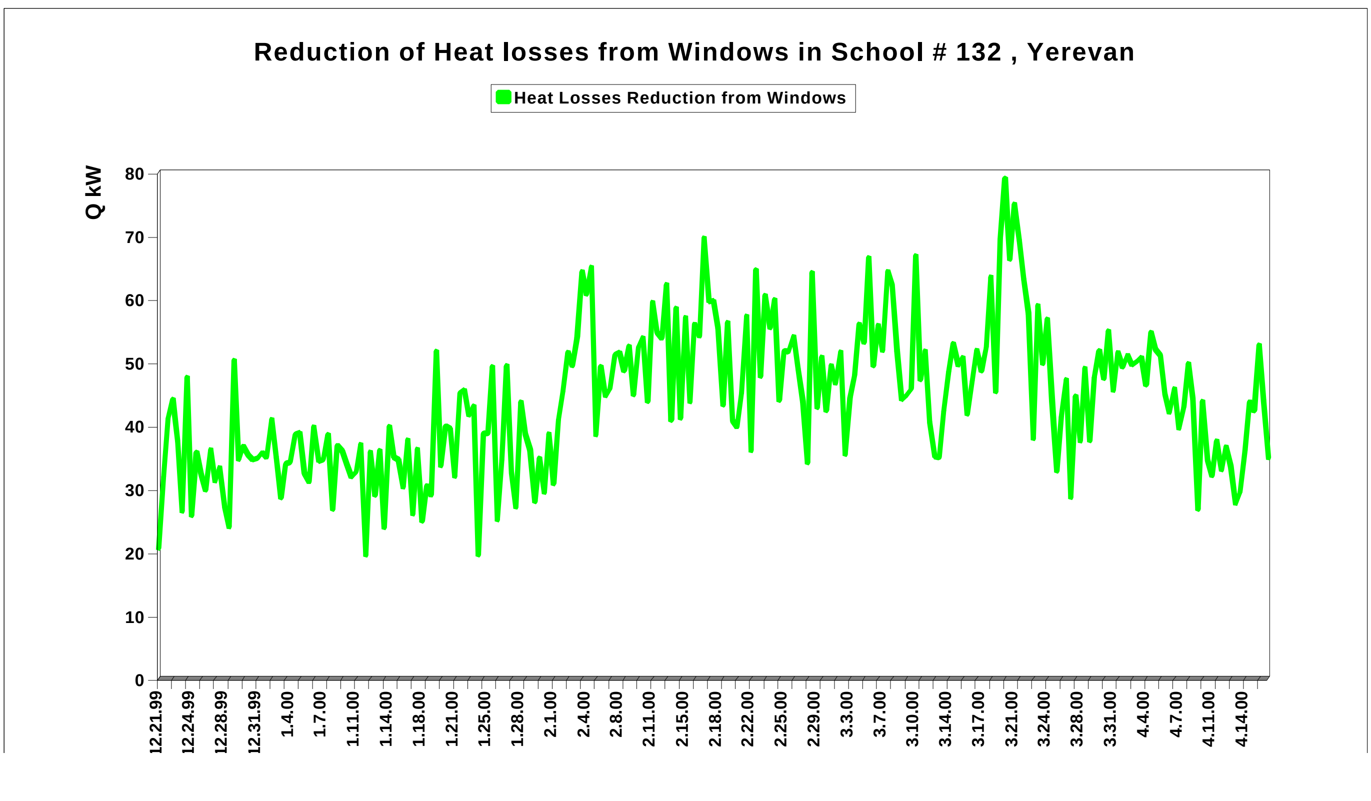
saved heat power ***DQ inf.av., kW,*** **due to weatherization:**

$$DQ\ inf.av. = 43,51\ kW - 3,54\ kW = 39,97\ kW$$

The quantity of heat, ***DQ inf.m.p., kWh,*** **saved during the monitoring period**:

$$DQ\ inf.m.p. = 39,97 \times 2400 = 95\ 940\ kWh$$

The quantity of electricity, saved in existing electric heaters, during the monitoring period:



DQ ***inf.m.p. = 95 940 kWh.***

The cost of saved electricity during the monitoring period is:

$D\,Ce = 95\,940 \times 0{,}05 = \$\,4797$

ESTIMATION OF THE REAL IMPACTS OF USE OF HIGH EFFICIENCY GAS BOILER IN SCHOOL SIRVANZADE DURING THE MONITORING PERIOD

The specific value of saved money:

$$DC_s = \$\,0{,}0051\,/m^{3o}C$$

Money, saved during the monitoring period, due to implementation of the boiler
(in case of operation of new boiler in school Shirvanzade, Yerevan, having volume 24960 m^3 and
tin.av.w.m.p – tout.av.m.p. = 13,25 ^oC):

$$DC_{s.i} = \$\,0{,}0051\,/m^{3o}C \times 24\,960\,m^3 \times 13{,}25\,^oC = \$\,1687$$

The total cost of savings due to weatherization and use of boiler during the monitoring period:

$$T = \$\,4797 + \$\,1687 = \$\,6484$$

ASSESSMENT OF THE IMPACTS OF WEATHERIZATION DURING THE HEATING PERIOD IN STANDARD COMFORT CONDITIONS IN BUILDINGS

tout.av.h.p = -0,5^{o}C;
Volume of the building – 24960m^3;
Heating period - 3500h;
Number of windows-667;
Kw+Kd = $16 432 + $7200 = $23 632cost of weatherization and installation of new entrance doors
Kb = $ 17337.Cost of gas boiler implementation project -

The quantity of heat, $DQ_{inf.h.p.}$, ***kWh,*** saved during the heating period, due to weatherization, in standard comfort conditions, when the inside temperature is t_{in}**=18^{o}C,** and outside average temperature for Yerevan is: tout.av.h.p = - 0,5^{o}C:

$$DQ_{inf.h.p.} = 12{,}4 \times 667 \times 1{,}01 \times 1{,}3 \times (18 + 0{,}5) \times 3500 / 3600 = 195\,321\,kWh$$

The quantity of saved electricity during the heating period due to weatherization:

$DQ_{inf.h.p} = 195\,321\,kWh$

The cost of saved electricity due to weatherization:

$D\,C_{e.w.} = 195\,321\,kWh \times 0{,}05 = \$\,9766$ ***per season,***

The seasonal heating load of whole weatherized building (according to the audit):

$Q_{h.p} = 533\,777\,kWh,$

The seasonal quantity of saved electricity:

$Q_{h.p,} = 533\,777\,kWh\,.$

The cost of saved electricity:

$C_{e.b.} = 533\,777\,kWh \times 0{,}05 = 26\,690\,\$\,/\,season,$

The quantity of gas, consumed by the boiler during the heating period:

$$G_g = 533\,777\ kWh \times 3600 / 35\,530 \times 0{,}94 = 57\,536\ m^3 / season,$$

The cost of gas, consumed by the boiler during the heating period:

$$Cg = 57\,536\ m^3 / season \times 102 / 1000 = 5\,870\ \$ / season.$$

The money saving due to replacement of electric heating by gas boiler:

$$DC_b = \$26\,690 – \$5\,870 = 20\,820\ \$ / season.$$

Total money saving during the heating period due to weatherization and use of the boiler:

$$(DC_{e.w} + DC_b) = \$\ 9766\ \$ / season + 20\,820\ \$ / season = \$\ 30\,586\ per\ season.$$

Total capital investment for implementation of weatherization and gas boiler installation projects: K = (Kw +Kd) + Kb = $23 632 + $ 17337 = $40969.

The simple pay-back period of capital investments for weatherization and implementation of the boiler in the Shirvanzade School # 21 in Yerevan:

$$P_{BP} = K / (DC_{e.w} + DC_b) = \$\ 40\,969 / 30\,586\ \$/season = 1{,}34\ season.$$

School # 132 in Yerevan

Building Characteristics

Constructed in 1967 by concrete blocks
Educational blocks – Block # 1 4 floors / 45 rooms (27 classrooms, 6 administrative rooms, 12 toilets)
Block # 2 3 floors / 16 rooms (11 classroom , 1 office , 4 toilets)
Block # 3 3 floor / 30 rooms (22 classroom , 2 offices , 6 toilets)
Sport hall block – 1floor / 2 sport halls with 4 cloak-rooms, 4 toilets , 3 offices, 2 classroom .
Buffet block – 1 floor / big dinning room , 5 kitchen rooms
Operating capacity – 1792 people.
Main sources of heating were electricity .
New boiler with COP = % 94 was installed.
The boiler hasn't been in use because of the termination of the heating season

Quantitative Results

Actual

Temperature in weatherized room is higher by 8-9 ^{0} C
tin.av.w.m.p. = 15,9 ^{0}C; tin.av.n-w.m.p = 7,57 ^{o}C; tout.av.m.p. = - 0,63 ^{0}C.
Average infiltration air volume in non-weatherized rooms - Vinf.av. n-w.m.p. = 13.9 m^3/h per window;
Average infiltration air volume in weatherized rooms - Vinf.av.w.m.p. = 1.42 m^3/h per window;
Heat losses from infiltration were reduced by 94 %
Monitoring period = 2400 hours
Energy saving for monitoring period due to weatherization – 111066 kWh
Energy cost saving for monitoring period due to weatherization - $ 5553

Theoretical

Heating period = 3500 hours
Energy savings for heating period due to weatherization =181256 kWh
Money saving = $9063
Energy saving for heating period due to the replacement of electric heating by the boiler- 577600kWh
Money saving for heating period = $ 28880

Total money saving during heating period due to weatherization and use of the boiler - $37943
Payback period = 1,73 heating season

ASSESSMENT OF THE REAL IMPACTS OF WEATHERIZATION DURING THE MONITORING PERIOD

Using the above monitored data, the realistic values of heat power for heating the infiltrated air from outside average temperatures to the levels of inside average temperatures for weatherized ***Qw,kW,*** and non-weatherized ***Qn.w., kW,*** rooms of all schools are calculated.

For weatherized rooms:

$$Qw. = 1,42 \times 615 \times 1,01 \times 1,3 \times (15,9 + 0,63) / 3600 = 5,26\ kW$$

For non-weatherized rooms:

$$Qn.w. = 13.9 \times 615 \times 1,01 \times 1,3 \times (15,9 + 0,63) / 3600 = 51,54\ kW$$

saved heat power *DQ inf.av., kW,* due to weatherization:

$$DQ\ inf.av. = 51,54\ kW - 5,26\ kW = 46,28\ kW$$

The quantity of heat, *DQ inf.m.p., kWh,* saved during the monitoring period:

$$DQ\ inf.m.p. = 46,28 \times 2400 = 111\ 066\ kWh$$

The quantity of electricity, saved in existing electric heaters, during the monitoring period:

$$DQ\ inf.m.p. = 111\ 066 kWh.$$

The cost of saved electricity during the monitoring period is:

$$D\ Ce = 111\ 066 \times 0,05 = \$\ 5553$$

ESTIMATION OF REAL IMPACTS OF USE OF HIGH EFFICIENCY GAS BOILER IN SCHOOL SIRVANZADE DURING THE MONITORING PERIOD

The specific value of saved money:

$$DC_s = \$\ 0,0051 / m^{3o}C$$

Money, saved during the monitoring period, due to implementation of the boiler

(in case of operation of new boiler in school #132, Yerevan having volume 22584 m^3 and

tin.av.w.m.p – tout.av.m.p. = 16,53 ^oC):

$$DC_{s.i} = \$\ 0,0051 / m^{3o}C \times 22\ 584\ m^3 \times 16,53\ ^oC = \$\ 1904$$

The total cost of savings due to weatherization and use of boiler during the monitoring period:

$$T = \$\ 5553 + \$\ 1904 = \$\ 7457$$

ASSESSMENT OF THE IMPACTS OF WEATHERIZATION DURING THE HEATING PERIOD IN STANDARD COMFORT CONDITIONS IN BUILDINGS

tout.av.h.p = -0,5^oC;
Volume of the building – 22 584m^3;

Heating period - 3500h;
Number of windows-615;
Kw+Kd = $18 032 + $4350 = $22 382Cost of weatherization and installation of new entrance doors
Kb = $ 43 105.Cost of boiler implementation project -

The quantity of heat, $DQ_{inf.h.p.}$, **kWh,** saved during the heating period, due to weatherization, in standard comfort conditions, when the inside temperature is $t_{in}=18^{o}C$, and outside average temperature for Yerevan is: tout.av.h.p = - 0,5^{o}C:

$$DQ_{inf.h.p.} = 12{,}48 \text{ x } 615 \text{ x } 1{,}01 \text{ x } 1{,}3 \text{ x } (18 + 0{,}5) \text{ x } 3500 / 3600 = 181\ 256 \text{ kWh}$$

The quantity of saved electricity during the heating period due to weatherization:

$$DQ_{inf.h.p} = 181\ 256 \text{ kWh}$$

The cost of saved electricity due to weatherization:

$$D\ C_{e.w.} = 181\ 256 \text{ kWh x } 0{,}05 = \$\ 9063 \text{ per season,}$$

The seasonal heating load of whole weatherized building (according to the audit):

$$Q_{h.p} = 740\ 420 \text{ kWh,}$$

The seasonal quantity of saved electricity:

$$Q_{h.p,} = 740\ 420 \text{ kWh .}$$

The cost of saved electricity:

$$C_{e.b.} = 740\ 420 \text{ kWh x } 0{,}05 = 37\ 021 \ \$ / \text{season,}$$

The quantity of gas, consumed by the boiler during the heating period:

$$G_g = 740\ 420 \text{ kWh x } 3600 / 35\ 530 \text{ x } 0{,}94 = 79\ 810 \ m^3 / \text{season,}$$

The cost of gas, consumed by the boiler during the heating period:

$$Cg = 79\ 810 \ m^3 / \text{season x } 102 / 1000 = 8\ 140 \ \$ / \text{season.}$$

The money saving due to replacement of electric heating by gas boiler:

$$DC_b = \$37\ 021 - \$\ 8\ 140 = 28\ 880 \ \$ / \text{season.}$$

Total money saving during the heating period due to weatherization and use of the boiler:

$$(DC_{e.w} + DC_b) = 9063 \ \$ / \text{season} + 28\ 880 \ \$ / \text{season} = \$\ 37\ 943 \text{ per season.}$$

Total capital investment for implementation of weatherization and gas boiler installation projects: K = (Kw +Kd) + Kb = $22 382 + $ 43 105 = $ 65 487

The simple pay-back period of capital investments for weatherization and implementation of the boiler in the School # 132 Yerevan building:

$$P_{BP} = K / (DC_{e.w} + DC_b) = \$65\ 487 / 37\ 943 \ \$/ \text{ per season} = 1{,}73 \text{ season.}$$

Formulas and methods used for calculations

METHOD FOR DETERMINATION OF REAL IMPACTS OF WEATHERIZATION DURING THE MONITORING PERIOD

The realistic values of heat power for heating the infiltrated air from outside average temperatures to the levels of inside average temperatures for weatherized and non-weatherized rooms can be calculated by the following formulas:

For weatherized rooms:

$$Qw. = Vinf.av.w.m.p. \times Nw \times Cair \times \rho\ air \times (tin.av.w.m.p - tout.av.m.p.) / 3600$$

For non-weatherized rooms:

$$Qn.w. = Vinf.av.\ n\text{-}w.m.p. \times Fw \times Cair \times \rho\ air \times (tin.av.w.m.p - tout.av.m.p.) / 3600$$

***Where:* Qw.** - *heat power for heating the infiltrated air for weatherized rooms, kW,*
Qn.w. - *heat power for heating the infiltrated air for non-weatherized rooms, kW,*
Nw – *total numer of windows of buildings, m^2,*
C air – *specific heat value for air, C air = 1,01 kJ / kg ^0C*
ρ **air** – *density of air, ρ air = 1,3 kg / m^3*

The represented formulas are based on the assumption that the heat power for non-weatherized rooms ***Qn.w.,kW,*** should be enough for providing the same inside temperature as it is in the weatherized rooms **(*tin.av.w.m.p)***. This approach is correct, thus it gives the real value of heat saving due to weatherization.

The difference between heat powers for providing the same inside temperatures in both non-weatherized and weatherized rooms is the saved heat power Δ***Q inf.av., kW***, due to weatherization:

$$\Delta Q\ inf.av. = Qinf.av\ n\text{-}w.m.p. - Qinf.av.w.m.p$$

$$\text{or} \quad \Delta Q\ inf.av. = \Delta\ V\ inf.av. \times Fw \times Cair \times \rho\ air \times (tin.av.w.m.p - tout.av.m.p.) / 3600$$

The quantity of heat, Δ***Q inf.m.p., kWh,*** saved during the monitoring period due to weatherization is determined by the following production:

$$\Delta Q\ inf.m.p. = \Delta Q\ inf.av. \times Zm.p$$

where: ***Zm.p*** – *number of hours of the monitoring period, h.*

The quantity of electricity, saved in existing electric heaters, during the monitoring period due to weatherization is determined by the previous formula and equal to Δ***Q inf.m.p., kWh.***

The cost of saved electricity during the monitoring period is:

$$\Delta\ Ce = \Delta Q\ inf.m.p. \times Te$$

where: ***Te*** – tariff for electricity used in the schools for heating , ***Te = 0,05 $/kWh***

METHOD FOR ESTIMATION OF REAL IMPACTS OF USE OF HIGH EFFICIENCY GAS BOILER FOR HEATING DURING THE MONITORING PERIOD

For providing the normal climatic conditions in classrooms with higher energy efficiency it was decided simultaneously with the weatherization of school buildings to use high efficiency gas-fired boilers instead of existing electric heaters. The implementation of high efficiency gas – fired heating boilers in weatherized school buildings provides the replacement of electric heaters by water heating systems. This change brings to the use of natural gas as an energy resource for heating. The immediate impact from the use of the natural gas for heating instead of electricity is the decrease of the cost for heating. The first gas boiler is installed in the school #1 building in Spitak. For reviling the cost effectiveness of the gas boiler a monitoring was accomplished. The goal of the monitoring is the measuring of the gas consumption by the boiler during the monitoring period, having provided the standard comfort inside temperatures (18^oC) in classrooms. By the values of measured quantity of consumed gas and number of hours of monitoring period can be determined the quantity of heat produced by the heating boiler. On the basis of comparison of costs for heat produced by boiler and electric heaters can be estimated the cost effectiveness of boiler project.

<u>The estimated quantity of heat Qb, kWh,</u> produced by the boiler during the monitoring period is determined by the following formula:

$$\mathbf{Qb = Vg \times q \times 0{,}94 / 3600 , \qquad kWh}$$

where: V_g – volume of the gas, consumed during the monitoring period, cub.m ;

q – specific heating value of gas combustion, q = 35 530 kJ / m^3 ;

0,94 – COP of the boiler.

<u>The cost of consumed gas</u> will be: $\mathbf{C_g = T_g \times V_g / 1000}$**, USD**

where: $\mathbf{T_g}$ – cost for 1000 m^3 of gas, $\mathbf{T_g}$ **= $102.**

<u>The estimated quantity of electricity</u> needed for producing heat $\mathbf{Q_b}$**, kWh,** generated by the boiler during the monitoring period is the same $\mathbf{Q_b}$**, kWh.**

<u>The cost of consumed electricity</u> will be: $\mathbf{C_e = T_e \times Q_b}$**, USD**

where $\mathbf{T_e}$ **= $0,05 / kWh,** tariff for electricity.

<u>The difference between the costs</u> of consumed electricity and gas is the money, saved during the monitoring period, due to implementation of the boiler: $DC_b = C_e - C_g$ ***, USD.***
The specific value of saved money, DC_s ***, $ / m³ °C,*** due to boiler, referred to 1 m^3 of building and 1 ^oC of difference between inside and outside average temperatures during the monitoring period makes:

$$DC_s = DC_b / V_b \times (tin.av.w.m.p - tout.av.m.p.)$$

The value of DC_s can be used for estimation of money, in case of later implementation of the boilers in other school buildings, having other volumes and located in other climatic conditions. It can be done by the following formula:

$$DC_{s.i} = DC_s \times V_{b.i} \times (tin.av.w.m.p - tout.av.m.p.)_i$$

METHOD FOR DETERMINATION OF IMPACTS OF WEATHERIZATION DURING THE HEATING PERIOD IN STANDARD COMFORT CONDITIONS IN BUILDINGS

The quantity of heat, $DQ_{inf.h.p.}$, kWh, saved during the heating period, due to weatherization, in standard comfort conditions, when the inside temperature is t_{in}**=18°C,** and outside average temperature is taken for given climatic conditions, can be determined by the following formula:

$$DQ_{inf.h.p.} = D\,V_{inf.av.} \times N_w \times C_{air} \times r_{air} \times (t_{in} - t_{out.av.h.p.}) \times Z_{h.p} / 3600$$

where: $t_{out.av.h.p}$ - outside average temperature, taken for given climatic conditions, **°C,**
$Z_{h.p}$ – number of hours of the heating period (season), h.

The quantity of saved electricity in existing electric heaters, during the heating period due to weatherization is determined by the previous formula and equal to $DQ_{inf.h.p.}$, kWh.

The cost of saved electricity during the heating period due to weatherization is determined by the formula: $D\,C_{e.w.} = DQ_{inf.h.p.} \times T_e$, $\$ / season$,
where: T_e – tariff for electricity used in the schools for heating , $T_e = 0{,}05$ $/kWh
The cost of saved electricity $C_{e.b}$, $/season, due to the use of boilers, during the heating period, should be calculated by the formula: $C_{e.b.} = Q_{h.p..} \times T_e$, $\$ / season$,
where: $Q_{h.p}$ - seasonal heating load of whole weatherized building, kWh.
The seasonal heating load of whole weatherized building, $Q_{h.p}$, kWh, should be taken from the schools energy audit reports, prepared before the beginning of the project.
The seasonal quantity of saved electricity is equal to $Q_{h.p}$, kWh.
The cost of gas, G_g, m^3 / season, consumed by the boiler during the heating period, is calculated by the formula: $Cg = Gg \times Tg$, $\$ / season$.
The quantity of gas, G_g, m^3 / season, consumed by the boiler during the heating period, in standard comfort conditions, when the inside temperature is t_{in}**=18°C,** and outside average temperature is taken for given climatic conditions, can be determined by the following formula:

$$G_g = Q_{h.p,} \times 3600 \ / \ q \times 0{,}94$$

The money saving due to replacement of electric heating by gas boiler heating during the heating standard season is determined by the following difference: $DC_b = C_e - C_g$, $\$ / season$.

The simple pay-back period of capital investments for implementation of weatherization in buildings is determined by the formula: $P_{BP} = (K_w + K_b) / (DC_e + DC_b)$,
where: P_{BP} – *pay back period of total capital investments, seasons,*
K_w – *total capital investments in weatherization,, USD.*
K_b - *total capital investments in implementation of boilers, USD.*
$(DC_e + DC_b)$ - *total money saving during the heating period due to weatherization and use of boilers, $ / seson.*

Appendix B
Comments Section from ESCO Survey

ESCO Survey

A. General Information Bagrat Kanayan "Kanayan & Co" Ltd.

1. How many employees did you have working on the ESCO project?
   3-5 employees
2. Please provide any suggestions you have to improve the ESCO Development Program.
More information is needed in terms on new methods, techniques that are currently utilized in the field of energy activities.
3. What would have made your job easier?
More knowledge and expertise in the provision of energy services and higher degree of organization of the local workers.

4. What was the biggest problem you had in doing the work?
The necessity to use simultaneously both modern foreign equipment and Soviet-made one was one of the biggest problems.
5. Please share any general comments about the ESCO Development Program.
   No special comments, but one - to continue this project.

. What are your suggestions for increasing the market for energy services?

1) to adopt laws related to energy fuels, ESCOs, particularly, the law about heating systems, which would be directed to the more careful consumption of heating fuels.
2) To create more favorable tax environment for ESCOs

A. **General Information** Avetis Simonyan "Hayenergomontage" Ltd.

1. How many employees did you have working on the ESCO project?
   15 employees
2. Please provide any suggestions you have to improve the ESCO Development Program.
   It is important to have more information about up-to-date boilers that are manufactured now. We also need more information about foreign ESCOs to have the opportunity to exchange experience.
3. What would have made your job easier?
It would be better that all the construction works were scheduled on summer months. This would enable to complete all kinds of mounting and construction works before the beginning of the heating season.
4. What was the biggest problem you had in doing the work?
   The schedules of the construction works and equipment delivery were not timed to meet each other. This disrupted our work, particularly due to the delay of the burners.
5. Please share any general comments about the ESCO Development Program.
   The boiler house is located in a very convenient place, where it is possible to install another boiler and provide heating to the nearest nursery school and several 5-storey buildings.
7. What are your suggestions for increasing the market for energy services?
   It is necessary to reject the centralized heating system, which are mainly suitable for big cities. Instead, the heating should be provided from small local boiler houses equipped with modern gas-fired boilers which should have 95% COP and 1200-1700 kW capacity.

A. General Information Maksim Misakyan, Gazcomshin Ltd

1. How many employees did you have working on the ESCO project?
   In this project our company had 17 employees.
2. Please provide any suggestions you have to improve the ESCO Development Program.

- For any undertaking, the first and foremost condition is to have a market demand for energy services.
    - To select as many sites as possible
3. What would have made your job easier?
    - The stable social-economic condition in Armenia.
4. What was the biggest problem you had in doing the work?
    As elsewhere, the biggest problem was to begin the work.
5. Please share any general comments about the ESCO Development Program.
    I have no comments, just want to say thank you to all those, whose efforts have made this difficult undertaking possible.
7. What are your suggestions for increasing the market for energy services?
    - To try to solve the problems of resident buildings that currently have no heating.
    - To come up with a complex project, which will involve theoretical assessment of differences between the centralized heating system and locally installed boilers.
    - Rehabilitation and further maintenance (through privatization) of heating systems.
    - Availability of capital for business start-ups.

A. General Information Vilik Hakhverdyan "Hakhverdyan Shinmontage" Ltd

1. How many employees did you have working on the ESCO project?
    15-20 employees
2. Please provide any suggestions you have to improve the ESCO Development Program.
    Before the works are started it is necessary to submit to the contractors:
    - better defined the scope of work and the list of activities to be fulfilled
    - precise technical requirements
    - working drawings
    - exact schedule of equipment delivery
    - the list of requirements that each contractor is expected to ultimately meet
3. What would have made your job easier?
    - All the above-mentioned points
    - The customer should interference into the working process as little as possible.
4. What was the biggest problem you had in doing the work?
    Unavailability of some equipment and tools that could have helped to better fulfill the task. Solution of certain issues, for which the customer was responsible, was delayed.
5. Please share any general comments about the ESCO Development Program.
    No comments
7. What are your suggestions for increasing the market for energy services?
    - To increase the availability of information
    - To enhance the utilization of solar energy
    - To decrease the heat loss from buildings
    - To learn the experience of more developed countries in the provision of energy services

A. General Information Mikroclima Ltd.

1. How many employees did you have working on the ESCO project?
2. Please provide any suggestions you have to improve the ESCO Development Program.
    1) organize training workshops
    2) to organize the implementation of new projects
3. What would have made your job easier?

Setting up the local manufacturing of e.g. boilers, materials within the framework of ESCOs

4. What was the biggest problem you had in doing the work?
   To try to keep the qualified labor force until the implementation of new projects
5. Please share any general comments about the ESCO Development Program.
   It gives employment opportunities to many people. The project is aimed at increasing the energy savings, fuel consumption savings as well as better protecting the environment.

7. What are your suggestions for increasing the market for energy services?

Further development of ESCOs and their training in terms of marketing activities, project management, advertising, and energy audits.

A. General Information Realshin Ltd. Azat Sakanyan

1. How many employees did you have working on the ESCO project?
   10 employees
2. Please provide any suggestions you have to improve the ESCO Development Program.
   I wish that these projects were continued.
3. What would have made your job easier?
   Nothing was particularly difficult.
4. What was the biggest problem you had in doing the work?
   No big problems
5. Please share any general comments about the ESCO Development Program.
   No comments

7. What are your suggestions for increasing the market for energy services?

Again, I can suggest that more similar projects be implemented, which help to provide the market for energy activities.

A. General Information RMAr, Vahe Melikyan

1. How many employees did you have working on the ESCO project?
   4 employees
2. Please provide any suggestions you have to improve the ESCO Development Program.

For better implementation of similar projects, it is necessary to start the funding and construction by early spring and not by winter, as the case was with this project.

3. What would have made your job easier?

There were no special problems. The only thing to note is that it would have been much better if the governmental bodies had displayed more interest and assisted in the implementation of the project.

4. What was the biggest problem you had in doing the work?

The biggest problem from the technical point of view is the difficulty to assess the heating systems actual condition, which hampers the calculation of the real costs needed for rehabilitation.

5. Please share any general comments about the ESCO Development Program.

One of the requirements was that schools should contribute 10% of the project cost for the implementation of the project. We encountered big problems while collecting this money. In order to avoid problems in the future, it would be much better that the school administrations meet the cost share requirement before the works actually begin.

7. What are your suggestions for increasing the market for energy services?

   First, to grant tax exemptions to companies, which render energy services, particularly energy-efficient ones. Second, there should be cooperation between ESCOs and manufacturers that produce high efficiency equipment. Third, to provide loans to ESCOs on more favorable grounds.

A. General Information Service Ltd.

1. How many employees did you have working on the ESCO project?
   14 employees
2. Please provide any suggestions you have to improve the ESCO Development Program.
   New project should be developed where our ESCOs would acquire knowledge and experience in the provision of various types of energy services.
3. What would have made your job easier?

If the works had been scheduled on warmer months of the year.

4. What was the biggest problem you had in doing the work?
   The biggest problem appeared to be the delay of the Giumry gas line construction, which prevented our work from being completed on time.
5. Please share any general comments about the ESCO Development Program.

We wish that the heating systems condition of the buildings had been analyzed and evaluated more carefully before the beginning of the project.

7. What are your suggestions for increasing the market for energy services?
   The government and other donor organization should be better informed about ESCOs activities, which can be a potential force to fill the demand for efficient services in the energy field.

A. General Information VN Ltd.

1. How many employees did you have working on the ESCO project?
   20 employees
2. Please provide any suggestions you have to improve the ESCO Development Program.
   I wish that the Street lighting project had been also implemented. I think that more similar projects in the future should be realized.
3. What would have made your job easier?
   We didn’t encounter difficulties.
4. What was the biggest problem you had in doing the work?
   There were no big problems.
5. Please share any general comments about the ESCO Development Program.

It would be better to foresee the alternative source of heating in the boiler house or to install two boilers rather than one.

7. What are your suggestions for increasing the market for energy services?
   - To create favorable conditions for local manufacturers, to enable them to produce high efficiency equipment.
   - To base the energy policy of the government on the criterion of energy efficiency.

Appendix C
Agenda and Participant List for ESCO Training

Appendix D
Agenda and Participant List for Heating Systems Workshop